Freescale Semiconductor, Inc.

MPC8240 Integrated Processor User's Manual

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About This Book

The primary objective of this user's manual is to define the functionality of the MPC8240 PowerPC™ integrated processor. The MPC8240 has a processor core based on the PowerPC 603e™ low-power microprocessor; it also performs many peripheral functions on-chip.

The MPC603e implements the full 32-bit portion of the PowerPC™ architecture. It is important to note that this book is intended as a companion to the following publications:

- The *MPC603e & EC603e RISC Microprocessor User's Manual*
- The *PowerPC Microprocessor Family: The Programming Environments*, (referred to as *The Programming Environments Manual*)

Contact your local sales representative to obtain a copy. Because the PowerPC architecture is designed to support a broad range of processors, *The Programming Environments Manual* provides a general description of features that are common to PowerPC processors and indicates those features that are optional or may be implemented differently in the design of each processor.

The information is subject to change without notice, as described in the disclaimers on the title page of this book. As with any technical documentation, it is the reader's responsibility to use the most recent version of the documentation. For more information, contact your sales representative.

Audience

This manual is intended for system software and hardware developers and applications programmers who want to develop products using the MPC8240 integrated processor. It is assumed that the reader understands operating systems, microprocessor system design, the basic principles of RISC processing, and details of the PowerPC architecture.

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Organization

Following is a list describing the major sections of this manual:

- Chapter 1, “Overview,” is for readers who want a general understanding of the features and functions of the MPC8240 device and its component parts.
- Chapter 2, “Signal Descriptions and Clocking,” provides descriptions of the MPC8240’s external signals. It describes each signal’s behavior when the signal is asserted and negated and when the signal is an input or an output.
- Chapter 3, “Address Maps,” describes how the MPC8240 in host mode supports the address map B configuration.
- Chapter 4, “Configuration Registers,” describes the programmable configuration registers of the MPC8240.
- Chapter 5, “PowerPC Processor Core,” provides an overview of the basic functionality of the G2 processor core.
- Chapter 6, “MPC107 Memory Interface,” describes the memory interface of the MPC8240 and how it controls the processor and PCI interactions to main memory.
- Chapter 7, “PCI Bus Interface,” provides a rudimentary description of PCI bus operations. The specific emphasis is directed at how the MPC8240 implements the PCI bus.
- Chapter 8, “DMA Controller,” describes how the DMA controller operates on the MPC8240.
- Chapter 9, “Message Unit (with I2O),” describes a mechanism to facilitate communications between host and peripheral processors.
- Chapter 10, “I2C Interface,” describes the I^2C (inter-integrated circuit) interface on the MPC8240.
- Chapter 11, “Embedded Programmable Interrupt Controller (EPIC) Unit,” provides a description of a general purpose interrupt controller solution using the EPIC module of the MPC8240.
- Chapter 12, “Central Control Unit,” describes the internal buffering and arbitration logic of the MPC8240 central control unit (CCU).
- Chapter 13, “Error Handling,” describes how the MPC8240 handles different error conditions.
- Chapter 14, “Power Management,” describes the many hardware support features provided by the MPC8240 for power management.
- Chapter 15, “Debug Features,” describes the MPC8240 features that aid in the process of system bring-up and debug.

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- Chapter 16, “Programmable I/O and Watchpoint,” describes the capabilities of the TRIG_IN signal, and how the TRIG_OUT signal can be generated based on programmable watchpoints on the internal processor bus.
- Appendix A, “Address Map A.” The MPC8240 supports two address maps. This appendix describes address map A.
- Appendix B, “Bit and Byte Ordering,” describes the big- and little-endian modes and provides examples of each.
- Appendix C, “Initialization Example,” contains an example PowerPC assembly language routine for initializing the configuration registers for the MPC8240 using address map B.
- Appendix D, “PowerPC Instruction Set Listings,” lists the MPC8240 microprocessor’s instruction set as well as the additional PowerPC instructions not implemented in the MPC8240.
- Appendix E, “Processor Core Register Summary,” summarizes the register set in the processor core of the MPC8240 as defined by the three programming environments of the PowerPC architecture.

Suggested Reading

This section lists additional reading that provides background for the information in this manual as well as general information about the PowerPC architecture.

General Information

The following documentation provides useful information about the PowerPC architecture and computer architecture in general:

- The following books are available from the PCI Special Interest Group, P.O. Box 14070, Portland, OR 97214; Tel. (800) 433-5177 (U.S.A.), (503) 797-4207 (International).
  - — *Local Bus Specification*, Rev 2.1
  - — *PCI System Design Guide*, Rev 1.0
- The following books are available from the Morgan-Kaufmann Publishers, 340 Pine Street, Sixth Floor, San Francisco, CA 94104; Tel. (800) 745-7323 (U.S.A.), (415) 392-2665 (International); web site: www.mkp.com; internet address: mkp@mkp.com.
  - — *The PowerPC Architecture: A Specification for a New Family of RISC Processors*, Second Edition, by International Business Machines, Inc.
  - — Updates to the architecture specification are accessible via the world-wide web at http://www.austin.ibm.com/tech/ppc-chg.html.
  - — *PowerPC Microprocessor Common Hardware Reference Platform: A System*

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Architecture, by Apple Computer, Inc., International Business Machines, Inc., and Motorola, Inc.

— *Macintosh Technology in the Common Hardware Reference Platform*, by Apple Computer, Inc.

— *Computer Architecture: A Quantitative Approach*, Second Edition, by John L. Hennessy and David A. Patterson

— *Computer Organization and Design: The Hardware/Software Interface*, Second Edition, by David A. Patterson and John L. Hennessy

- *Inside Macintosh: RISC System Software*, Addison-Wesley Publishing Company, One Jacob Way, Reading, MA, 01867; Tel. (800) 282-2732 (U.S.A.), (800) 637-0029 (Canada), (716) 871-6555 (International)

PowerPC Documentation

The PowerPC documentation is available from the sources listed on the back cover of this manual; the document order numbers are included in parentheses for ease in ordering:

- User's manuals—These books provide details about individual PowerPC implementations and are intended to be used in conjunction with *The Programming Environments Manual*.
- Programming environments manuals—These books provide information about resources defined by the PowerPC architecture that are common to PowerPC processors. The 32- bit architecture model is described in *PowerPC Microprocessor Family: The Programming Environments for 32-Bit Microprocessors*, Rev. 1: MPCFPE32B/AD (Motorola order #)
- *Implementation Variances Relative to Rev. 1 of The Programming Environments Manual* is available via the world-wide web at http://www.motorola.com/PowerPC/.
- Addenda/errata to user's manuals—Because some processors have follow-on parts an addendum is provided that describes the additional features and changes to functionality of the follow-on part. These addenda are intended for use with the corresponding user's manuals.
- Hardware specifications—Hardware specifications provide specific data regarding bus timing, signal behavior, and AC, DC, and thermal characteristics, as well as other design considerations for each PowerPC implementation.
- Technical Summaries—Each PowerPC implementation has a technical summary that provides an overview of its features. This document is roughly the equivalent to the overview (Chapter 1) of an implementation's user's manual.
- *PowerPC Microprocessor Family: The Bus Interface for 32-Bit Microprocessors:* MPCBUSIF/AD (Motorola order #) provides a detailed functional description of the 60x bus interface, as implemented on the 601, 603, and 604 family of PowerPC

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microprocessors. This document is intended to help system and chipset developers by providing a centralized reference source to identify the bus interface presented by the 60x family of PowerPC microprocessors.

- *PowerPC Microprocessor Family: The Programmer's Reference Guide*: MPCPRG/D (Motorola order #) is a concise reference that includes the register summary, memory control model, exception vectors, and the PowerPC instruction set.
- *PowerPC Microprocessor Family: The Programmer's Pocket Reference Guide*: MPCPRGREF/D (Motorola order #)
  This foldout card provides an overview of the PowerPC registers, instructions, and exceptions for 32-bit implementations.
- Application notes—These short documents contain useful information about specific design issues useful to programmers and engineers working with PowerPC processors.
- Additional literature on PowerPC implementations is being released as new processors become available. For a current list of PowerPC documentation, refer to the world-wide web at http://www.mot.com/SPS/PowerPC/.

Conventions

This document uses the following notational conventions:

mnemonics	Instruction mnemonics are shown in lowercase bold.
italics	Italics indicate variable command parameters, for example, **bcctr**x.
	Book titles in text are set in italics.
0x0	Prefix to denote hexadecimal number
0b0	Prefix to denote binary number
rA, **r**B	Instruction syntax used to identify a source GPR
rA|0	The contents of a specified GPR or the value 0.
rD	Instruction syntax used to identify a destination GPR
frA, **fr**B, **fr**C	Instruction syntax used to identify a source FPR
frD	Instruction syntax used to identify a destination FPR
REG[FIELD]	Abbreviations or acronyms for registers are shown in uppercase text. Specific bits, fields, or ranges appear in brackets. For example, MSR[LE] refers to the little-endian mode enable bit in the machine state register.
x	In certain contexts, such as a signal encoding, this indicates a don't care.

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n	Used to express an undefined numerical value
¬	NOT logical operator
&	AND logical operator
|	OR logical operator
||	Concatenate logical operator
0000	Indicates reserved bits or bit fields in a register. Although these bits may be written to as either ones or zeros, they are always read as zeros.

Acronyms and Abbreviations

Table i contains acronyms and abbreviations that are used in this document.

Table i. Acronyms and Abbreviated Terms

Term	Meaning
ALU	Arithmetic logic unit
BAT	Block address translation
BGA	Ball grid array package
BIST	Built-in self test
BIU	Bus interface unit
BPU	Branch processing unit
CAR	Cache address register
CAS	Column address strobe
CBR	CAS before RAS
CIA	Current instruction address
CMOS	Complementary metal-oxide semiconductor
CR	Condition register
CRTRY	Cache retry queue
CTR	Count register
DAR	Data address register
DBAT	Data BAT
DCMP	Data TLB compare
DEC	Decrementer register
DIMM	Dual in-line memory module
DRAM	Dynamic random access memory
DMISS	Data TLB miss address
DSISR	Register used for determining the source of a DSI exception
DTLB	Data translation lookaside buffer

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Table i. Acronyms and Abbreviated Terms (Continued)

Term	Meaning
EA	Effective address
EAR	External access register
ECC	Error checking and correction
EDO	Extended data out DRAM
ErrDR	Error detection register
ErrEnR	Error enabling register
FIFO	First-in-first-out
FPR	Floating-point register
FPSCR	Floating-point status and control register
FPU	Floating-point unit
GPR	General-purpose register
HASH1	Primary hash address
HASH2	Secondary hash address
IABR	Instruction address breakpoint register
IBAT	Instruction BAT
ICMP	Instruction TLB compare
IEEE	Institute for Electrical and Electronics Engineers
Int Ack	Interrupt acknowledge
IMISS	Instruction TLB miss address
IQ	Instruction queue
ISA	Industry standard architecture
ITLB	Instruction translation lookaside buffer
IU	Integer unit
JTAG	Joint test action group interface
L2	Secondary cache
LIFO	Last-in-first-out
LR	Link register
LRU	Least recently used
LSB	Least-significant byte
lsb	Least-significant bit
LSU	Load/store unit
MICR	Memory interface configuration register
MCCR	Memory control configuration register
MEI	Modified/exclusive/invalid
MESI	Modified/exclusive/shared/invalid—cache coherency protocol
MMU	Memory management unit

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Table i. Acronyms and Abbreviated Terms (Continued)

Term	Meaning
MSB	Most-significant byte
msb	Most-significant bit
MSR	Machine state register
Mux	Multiplex
NaN	Not a number
No-op	No operation
OEA	Operating environment architecture
PCI	Peripheral component interconnect
PCIB/MC	PCI bridge/memory controller
PICR	Processor interface configuration register
PID	Processor identification tag
PIR	Processor identification register
PLL	Phase-locked loop
PMC	Power management controller
PMCR	Power management configuration register
PTE	Page table entry
PTEG	Page table entry group
PVR	Processor version register
RAS	Row address strobe
RAW	Read-after-write
RISC	Reduced instruction set computing
ROM	Read-only memory
RPA	Required physical address
RTL	Register transfer language
RWITM	Read with intent to modify
SDR1	Register that specifies the page table base address for virtual-to-physical address translation
SDRAM	Synchronous dynamic random access memory
SIMM	Single in-line memory module
SPR	Special-purpose register
SR	Segment register
SRR0	Machine status save/restore register 0
SRR1	Machine status save/restore register 1
SRU	System register unit
TAP	Test access port
TB	Time base facility
TBL	Time base lower register

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Table i. Acronyms and Abbreviated Terms (Continued)

Term	Meaning
TBU	Time base upper register
TLB	Translation lookaside buffer
TTL	Transistor-to-transistor logic
UIMM	Unsigned immediate value
UISA	User instruction set architecture
UUT	Unit under test
VCO	Voltage-controlled oscillator
VEA	Virtual environment architecture
WAR	Write-after-read
WAW	Write-after-write
WIMG	Write-through/caching-inhibited/memory-coherency enforced/guarded bits
XER	Register used for indicating conditions such as carries and overflows for integer operations

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Chapter 1
Overview

This chapter provides an overview of theMPC8240 PowerPC™ integrated processor for high-performance embedded systems. The MPC8240 is a cost-effective, general-purpose integrated processor for applications using PCI in networking infrastructure, telecommunications, and other embedded markets. It can be used for control processing in applications such as network routers and switches, mass storage subsystems, network appliances, and print and imaging systems. For errata or revisions to this document, refer to the web site at http://www.motorola.com/semiconductors.

1.1 MPC8240 Integrated Processor Overview

The MPC8240 integrated processor is comprised of a peripheral logic block and a 32-bit superscalar PowerPC processor core, as shown in Figure 1-1.

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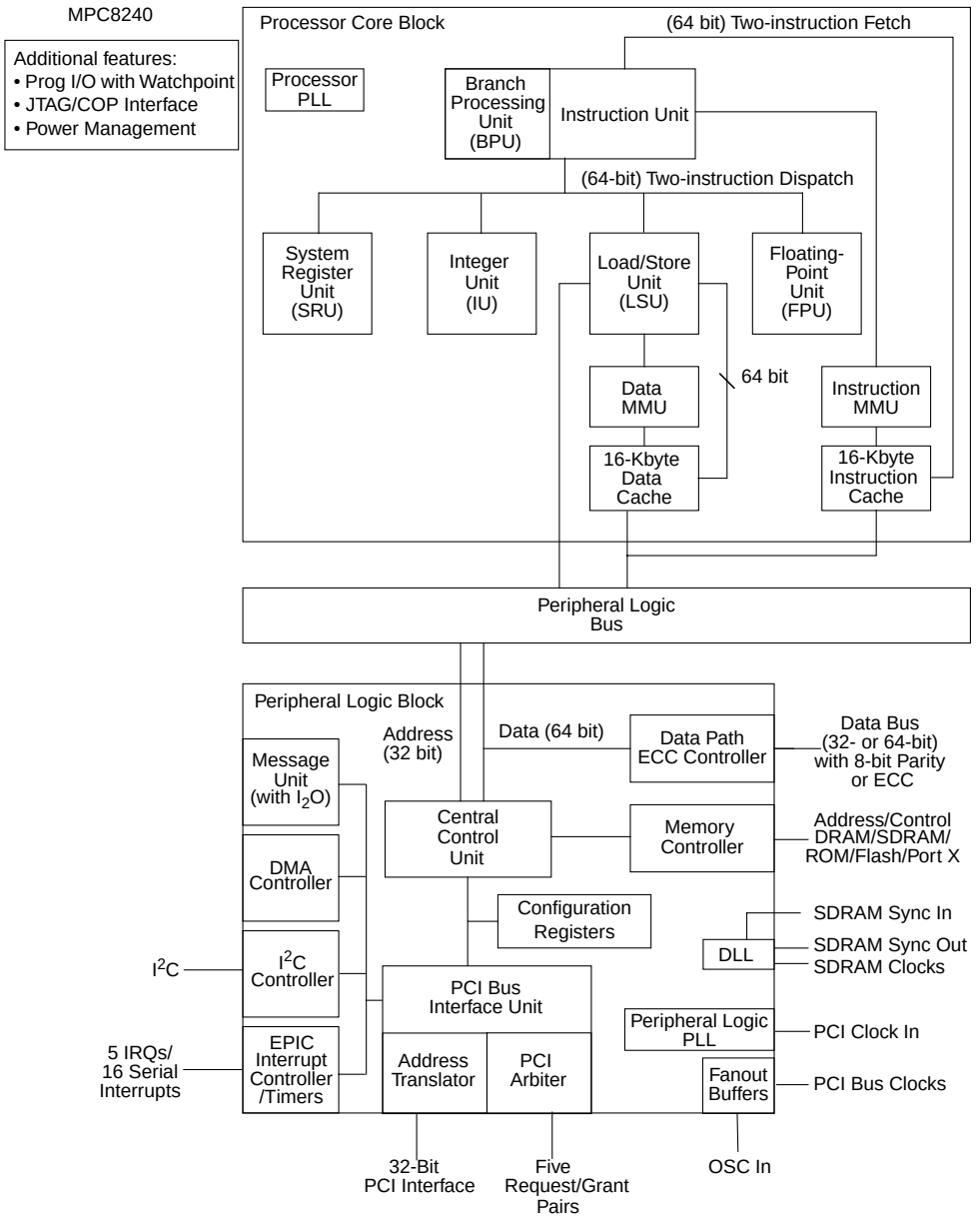

Figure 1-1. MPC8240 Integrated Processor Functional Block Diagram

The peripheral logic integrates a PCI bridge, memory controller, DMA controller, EPIC interrupt controller, a message unit (and I_2O controller), and an I^2C controller. The processor core is a full-featured, high-performance processor with floating-point support,

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memory management, 16-Kbyte instruction cache, 16-Kbyte data cache, and power management features. The integration reduces the overall packaging requirements and the number of discrete devices required for an embedded system.

The MPC8240 contains an internal peripheral logic bus that interfaces the processor core to the peripheral logic. The core can operate at a variety of frequencies, allowing the designer to trade off performance for power consumption. The processor core is clocked from a separate PLL, which is referenced to the peripheral logic PLL. This allows the microprocessor and the peripheral logic block to operate at different frequencies, while maintaining a synchronous bus interface. The interface uses a 64- or 32-bit data bus (depending on memory data bus width) and a 32-bit address bus along with control signals that enable the interface between the processor and peripheral logic to be optimized for performance. PCI accesses to the MPC8240's memory space are passed to the processor bus for snooping when snoop mode is enabled.

The processor core and peripheral logic are general-purpose in order to serve a variety of embedded applications. The MPC8240 can be used as either a PCI host or PCI agent controller.

1.1.1 MPC8240 Integrated Processor Features

This section summarizes the features of the MPC8240. Major features of the MPC8240 are as follows:

- Peripheral logic
  - — Memory interface
    - – Programmable timing supporting either FPM DRAM, EDO DRAM or SDRAM
    - – High-bandwidth bus (32-/64-bit data bus) to DRAM
    - – Supports one to eight banks of 4-, 16-, 64-, or 128-Mbit memory devices
    - – Supports 1-Mbyte to 1-Gbyte DRAM memory
    - – 16 Mbytes of ROM space
    - – 8-, 32-, or 64-bit ROM
    - – Write buffering for PCI and processor accesses
    - – Supports normal parity, read-modify-write (RMW), or ECC
    - – Data-path buffering between memory interface and processor
    - – Low-voltage TTL logic (LVTTL) interfaces
    - – Port X: 8-, 32-, or 64-bit general-purpose I/O port using ROM controller interface with programmable address strobe timing
  - — 32-bit PCI interface operating up to 66 MHz
    - – PCI 2.1-compliant

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- PCI 5.0-V tolerance
- Support for PCI locked accesses to memory
- Support for accesses to PCI memory, I/O, and configuration spaces
- Selectable big- or little-endian operation
- Store gathering of processor-to-PCI write and PCI-to-memory write accesses
- Memory prefetching of PCI read accesses
- Selectable hardware-enforced coherency
- PCI bus arbitration unit (five request/grant pairs)
- PCI agent mode capability
- Address translation unit
- Some internal configuration registers accessible from PCI

— Two-channel integrated DMA controller (writes to ROM/Port X not supported)

- Supports direct mode or chaining mode (automatic linking of DMA transfers)
- Supports scatter gathering—read or write discontinuous memory
- Interrupt on completed segment, chain, and error
- Local-to-local memory
- PCI-to-PCI memory
- PCI-to-local memory
- PCI memory-to-local memory

— Message unit

- Two doorbell registers
- Two inbound and two outbound messaging registers
- I_2O message controller

— I^2C controller with full master/slave support (except broadcast all)

— Embedded programmable interrupt controller (EPIC)

- Five hardware interrupts (IRQs) or 16 serial interrupts
- Four programmable timers

— Integrated PCI bus and SDRAM clock generation

— Programmable PCI bus and memory interface output drivers

- Dynamic power management—Supports 60x nap, doze, and sleep modes
- Programmable input and output signals with watchpoint capability
- Built-in PCI bus performance monitor facility

— Debug features

- Memory attribute and PCI attribute signals
- Debug address signals

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  - $\overline{\text{MIV}}$ signal: Marks valid address and data bus cycles on the memory bus.
  - Error injection/capture on data path
  - IEEE 1149.1 (JTAG)/test interface
- Processor core
  - — High-performance, superscalar processor core
  - — Integer unit (IU), floating-point unit (FPU) (software enabled or disabled), load/store unit (LSU), system register unit (SRU), and a branch processing unit (BPU)
  - — 16-Kbyte instruction cache
  - — 16-Kbyte data cache
  - — Lockable L1 cache—entire cache or on a per-way basis

1.1.2 MPC8240 Integrated Processor Applications

The MPC8240 can be used for control processing in applications such as routers, switches, multi-channel modems, network storage, image display systems, enterprise I/O processor, Internet access device (IAD), disk controller for RAID systems, and copier/printer board control. Figure 1-2 shows the MPC8240 in the role of host processor.

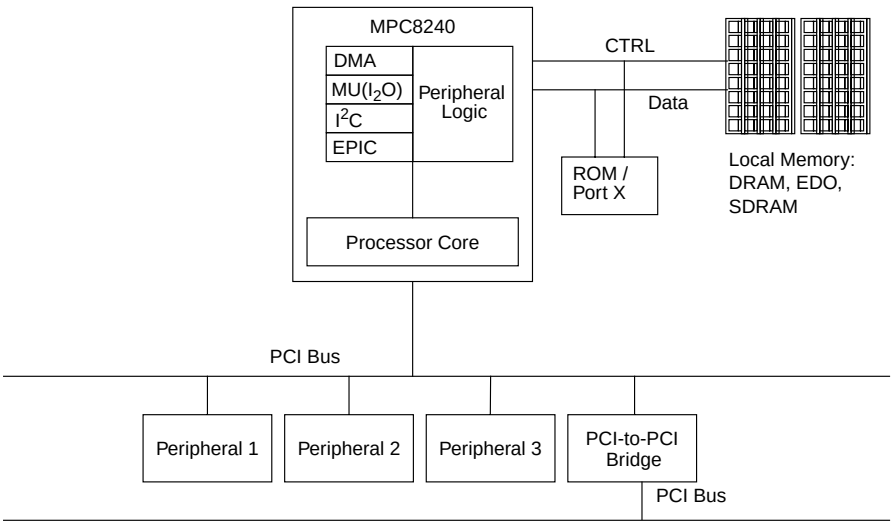

Figure 1-2. System Using an Integrated MPC8240 as a Host Processor

Figure 1-3 shows the MPC8240 in a peripheral processor application.

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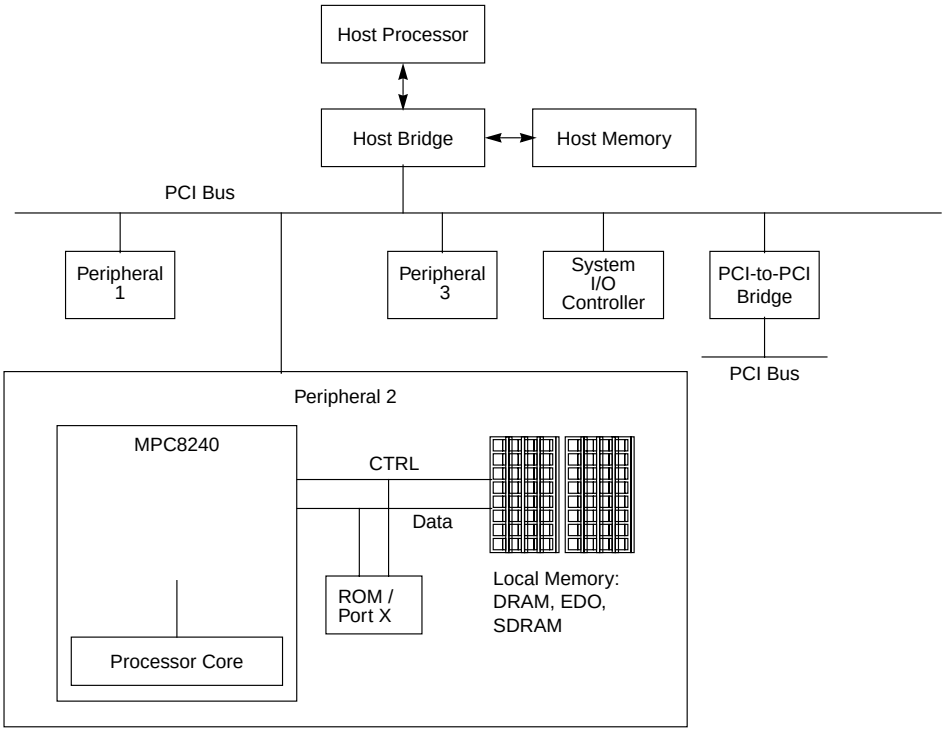

Figure 1-3. Embedded System Using an MPC8240 as a Peripheral Processor

Figure 1-4 shows the MPC8240 as a distributed I/O processing device. The PCI-to-PCI bridge shown could be of the PCI type 0 variety. The MPC8240 would not be part of the system configuration map. This configuration is useful in applications such as RAID controllers, where the I/O devices shown are SCSI controllers, or multi-port network controllers where the devices shown are Ethernet controllers.

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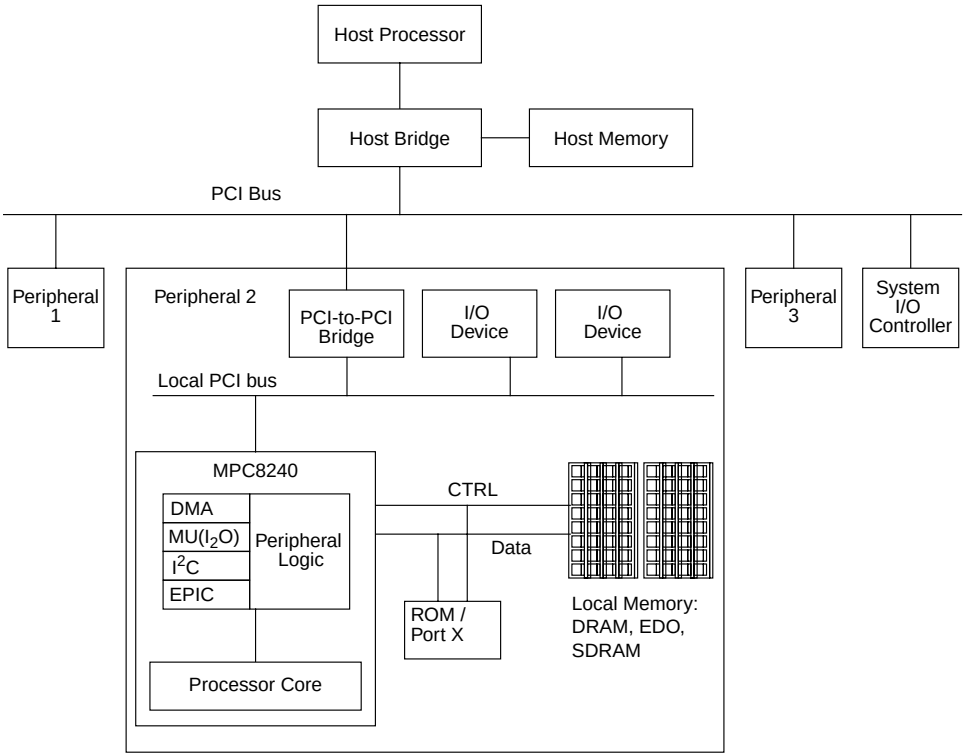

Figure 1-4. Embedded System Using an MPC8240 as a Distributed Processor

1.2 Processor Core Overview

The MPC8240 contains an embedded version of the PowerPC 603e™ processor. For detailed information regarding the processor refer to the following:

- *MPC603e & EC603e User's Manual* (Those chapters that describe the programming model, cache model, memory management model, exception model, and instruction timing)
- *PowerPC Microprocessor Family: The Programming Environments for 32-Bit Microprocessors*

This section is an overview of the processor core, provides a block diagram showing the major functional units, and describes briefly how those units interact. For more information, refer to Chapter 2, "PowerPC Processor Core."

The processor core is a low-power implementation of the PowerPC microprocessor family of reduced instruction set computing (RISC) microprocessors. The processor core implements the 32-bit portion of the PowerPC architecture, which provides 32-bit effective addresses, integer data types of 8, 16, and 32 bits, and floating-point data types of 32 and 64 bits.

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The processor core is a superscalar processor that can issue and retire as many as three instructions per clock. Instructions can execute out of order for increased performance; however, the processor core makes completion appear sequential.

The processor core integrates five execution units—an integer unit (IU), a floating-point unit (FPU), a branch processing unit (BPU), a load/store unit (LSU), and a system register unit (SRU). The ability to execute five instructions in parallel and the use of simple instructions with rapid execution times yield high efficiency and throughput. Most integer instructions execute in one clock cycle. On the processor core, the FPU is pipelined so a single-precision multiply-add instruction can be issued and completed every clock cycle.

The processor core supports integer data types of 8, 16, and 32 bits, and floating-point data types of 32 and 64 bits.

The processor core provides independent on-chip, 16-Kbyte, four-way set-associative, physically addressed caches for instructions and data and on-chip instruction and data memory management units (MMUs). The MMUs contain 64-entry, two-way set-associative, data and instruction translation lookaside buffers (DTLB and ITLB) that provide support for demand-paged virtual memory address translation and variable-sized block translation. The TLBs and caches use a least recently used (LRU) replacement algorithm. The processor also supports block address translation through the use of two independent instruction and data block address translation (IBAT and DBAT) arrays of four entries each. Effective addresses are compared simultaneously with all four entries in the BAT array during block translation. In accordance with the PowerPC architecture, if an effective address hits in both the TLB and BAT array, the BAT translation takes priority.

As an added feature to the processor core, the MPC8240 can lock the contents of one to three ways in the instruction and data cache (or an entire cache). For example, this allows embedded applications to lock interrupt routines or other important (time-sensitive) instruction sequences into the instruction cache. It allows data to be locked into the data cache, which may be important to code that must have deterministic execution.

The processor core has a selectable 32- or 64-bit data bus and a 32-bit address bus. The processor core supports single-beat and burst data transfers for memory accesses, and supports memory-mapped I/O operations.

Figure 1-5 provides a block diagram of the MPC8240 processor core that shows how the execution units (IU, FPU, BPU, LSU, and SRU) operate independently and in parallel. Note that this is a conceptual diagram and does not attempt to show how these features are physically implemented on the chip.

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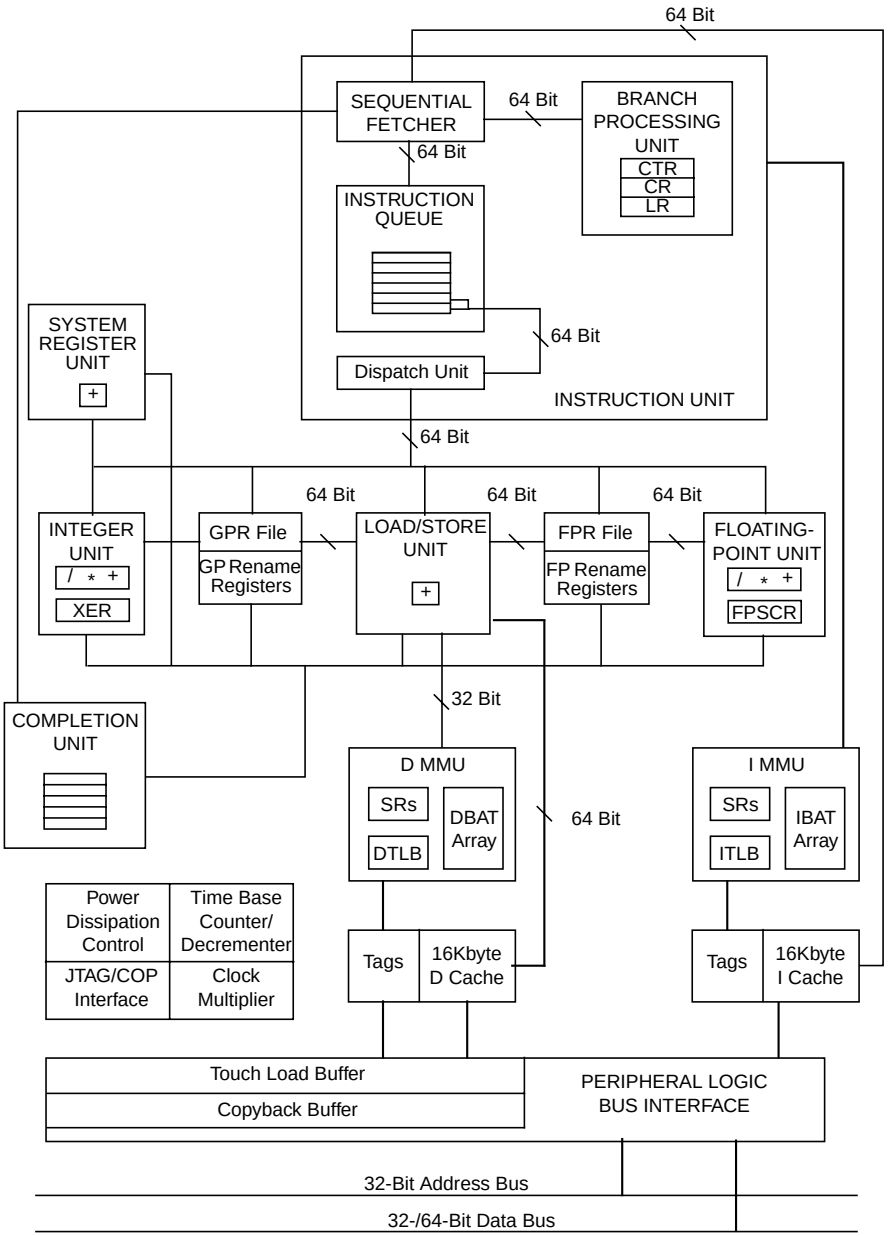

Figure 1-5. MPC8240 Integrated Processor Core Block Diagram

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1.3 Peripheral Logic Bus

The MPC8240 contains an internal peripheral logic bus that interfaces the processor core to the peripheral logic. The core can operate at a variety of frequencies allowing the designer to balance performance and power consumption. The processor core is clocked from a separate PLL, which is referenced to the peripheral logic PLL. This allows the microprocessor and the peripheral logic to operate at different frequencies while maintaining a synchronous bus interface.

The processor core-to-peripheral logic interface includes a 32-bit address bus, a 32- or 64-bit data bus as well as control and information signals. The peripheral logic bus allows for internal address-only transactions as well as address and data transactions. The processor core control and information signals include the address arbitration, address start, address transfer, transfer attribute, address termination, data arbitration, data transfer, data termination, and processor state signals. Test and control signals provide diagnostics for selected internal circuits.

The peripheral logic interface supports bus pipelining, which allows the address tenure of one transaction to overlap the data tenure of another. PCI accesses to the memory space are monitored by the peripheral logic bus to allow the processor to snoop these accesses (when snooping not explicitly disabled).

As part of the peripheral logic bus interface, the processor core's data bus is configured at power-up to either a 32- or 64-bit width. When the processor is configured with a 32-bit data bus, memory accesses on the peripheral logic bus interface allow transfer sizes of 8, 16, 24, or 32 bits in one bus clock cycle. Data transfers occur in either single-beat transactions, or two-beat or eight-beat burst transactions, with a single-beat transaction transferring as many as 32 bits. Single- or double-beat transactions are caused by noncached accesses that access memory directly (that is, reads and writes when caching is disabled, caching-inhibited accesses, and stores in write-through mode). Eight-beat burst transactions, which always transfer an entire cache line (32 bytes), are initiated when a line is read from or written to memory.

When the peripheral logic bus interface is configured with a 64-bit data bus, memory accesses allow transfer sizes of 8, 16, 24, 32, or 64 bits in one bus clock cycle. Data transfers occur in either single-beat transactions or four-beat burst transactions. Single-beat transactions are caused by noncached accesses that access memory directly (that is, reads and writes when caching is disabled, caching-inhibited accesses, and stores in write-through mode). Four-beat burst transactions, which always transfer an entire cache line (32 bytes), are initiated when a block is read from or written to memory.

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1.4 Peripheral Logic Overview

The peripheral logic block integrates a PCI bridge, memory controller, DMA controller, EPIC interrupt controller/timers, a message unit with an Intelligent Input/Output (I_2O) message controller, and an Inter-Integrated Circuit (I^2C) controller. The integration reduces the overall packaging requirements and the number of discrete devices required for an embedded system.

Figure 1-6 shows the major functional units within the peripheral logic block. Note that this is a conceptual block diagram intended to show the basic features rather than an attempt to show how these features are physically implemented.

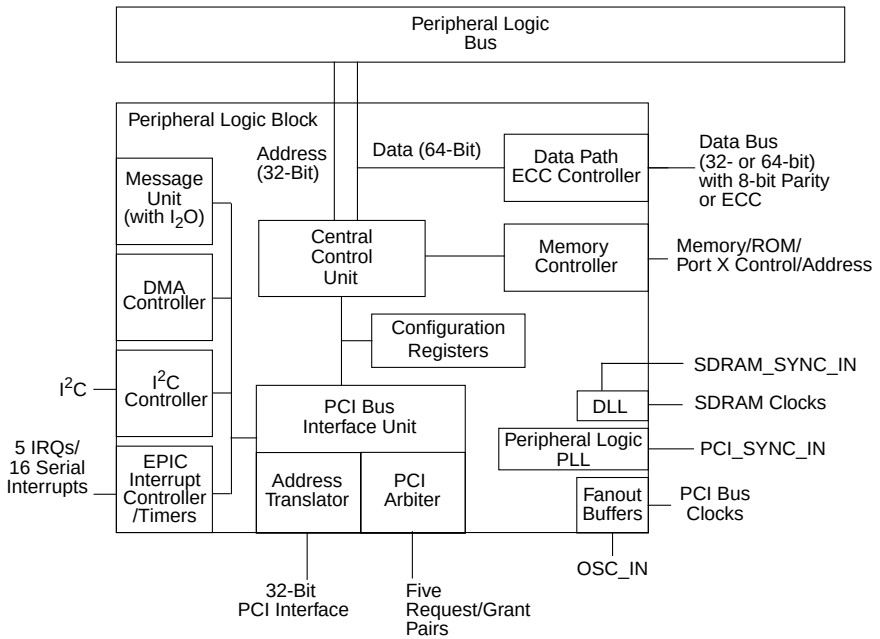

Figure 1-6. MPC8240 Peripheral Logic Block Diagram

1.4.1 Peripheral Logic Features

Major features of the peripheral logic are as follows:

- Peripheral logic bus
  - — Supports various operating frequencies and bus divider ratios
  - — 32-bit address bus, 64-bit data bus
  - — Supports full memory coherency

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  - — Decoupled address and data buses for pipelining of peripheral logic bus accesses
  - — Store gathering on peripheral logic bus-to-PCI writes
- Memory interface
  - — 1 Gbyte of RAM space, 16 Mbytes of ROM space
  - — High-bandwidth, 64-bit data bus (72 bits including parity or ECC)
  - — Supports fast page mode DRAMs, extended data out (EDO) DRAMs, or synchronous DRAMs (SDRAMs)
  - — Supports 1 to 8 banks of DRAM/EDO/SDRAM with sizes ranging from 1 to 128 Mbytes per bank
  - — Supports page mode SDRAMs—four open pages simultaneously
  - — DRAM/EDO configurations support parity or error checking and correction (ECC); SDRAM configurations support ECC
  - — ROM space may be split between the PCI bus and the memory bus (8 Mbytes each)
  - — Supports 8-bit asynchronous ROM, or 32- or 64-bit burst-mode ROM
  - — Supports writing to flash ROM
  - — Configurable data path
  - — Programmable interface timing
- PCI interface
  - — Compatible with PCI Local Bus Specification, Revision 2.1
  - — Supports PCI locked accesses to memory using the $\overline{\text{LOCK}}$ signal and protocol
  - — Supports accesses to all PCI address spaces
  - — Selectable big- or little-endian operation
  - — Store gathering on PCI writes to memory
  - — Selectable memory prefetching of PCI read accesses
  - — Interface operates at up to 66 MHz
  - — Parity support
- Supports concurrent transactions on peripheral logic bus and PCI buses

1.4.2 Peripheral Logic Functional Units

The peripheral logic consists of the following major functional units:

- Peripheral logic bus interface
- Memory interface
- PCI interface
  - — PCI bus arbitration unit
  - — Address maps and translation

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  - — Big-and little-endian modes
  - — PCI agent capability
  - — PCI bus clock buffers and bus ratios
- DMA controller
- Message unit
  - — Doorbell registers
  - — Message registers
  - — I_2O support (circular queues)
- Embedded programmable interrupt controller (EPIC) with four timers
- I^2C interface

1.4.3 Memory System Interface

The MPC8240 memory interface controls processor and PCI interactions to main memory. It supports a variety of DRAM, and Flash or ROM configurations as main memory. The MPC8240 supports fast page mode (FPM), extended data out (EDO) and synchronous DRAM (SDRAM). The maximum supported memory size is 1 Gbyte of DRAM or SDRAM and 16 Mbytes of ROM/Flash. SDRAM must comply with the JEDEC SDRAM specification.

The MPC8240 implements Port X, a memory bus interface that facilitates the connection of general-purpose I/O devices. The Port X functionality allows the designer to connect external registers, communication devices, and other such devices directly to the MPC8240. Some devices may require a small amount of external logic to generate properly address strobes, chip selects, and other signals.

The MPC8240 is designed to control a 32- or 64-bit data path to main memory DRAM or SDRAM. For a 32-bit data path, the MPC8240 can be configured to check and generate byte parity using four parity bits. For a 64-bit data path, the MPC8240 can be configured to support parity or ECC checking and generation with eight parity/syndrome bits checked and generated. Note that the data bus width (32- or 64-bit) chosen at reset for the 60x bus interface is also used for the memory interface.

The MPC8240 supports DRAM or SDRAM bank sizes from 1 to 128 Mbytes and provides bank start address and end address configuration registers. Note that the MPC8240 does not support mixed DRAM/SDRAM configurations. The MPC8240 can be configured so that appropriate row and column address multiplexing occurs according to the accessed memory bank. Addresses are provided to DRAM and SDRAM through a 13-bit interface for DRAM and a 14-bit interface for SDRAM.

Two chip selects, one write enable, one output enable, and up to 21 address signals are provided for ROM/Flash systems.

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1.4.4 Peripheral Component Interconnect (PCI) Interface

The PCI interface for the MPC8240 is compliant with the *Peripheral Component Interconnect Specification* Revision 2.1. The PCI interface provides mode-selectable, big- to little-endian conversion. The MPC8240 provides an interface to the PCI bus running at speeds up to 66 MHz.

The MPC8240's PCI interface can be configured as host or agent. In host mode, the interface acts as the main memory controller for the system and responds to all host memory transactions.

In agent mode, the MPC8240 can be configured to respond to a programmed window of PCI memory space. A variety of initialization modes are provided to boot the device.

1.4.4.1 PCI Bus Arbitration Unit

The MPC8240 contains a PCI bus arbitration unit, which eliminates the need for an external unit, thus lowering system complexity and cost. It has the following features:

- Five external arbitration signal pairs. The MPC8240 is the sixth member of the arbitration pool.
- The bus arbitration unit allows fairness as well as a priority mechanism.
- A two-level round-robin scheme is used in which each device can be programmed within a pool of a high- or low-priority arbitration. One member of the low-priority pool is promoted to the high-priority pool. As soon as it is granted the bus, it returns to the low-priority pool.
- The unit can be disabled to allow a remote arbitration unit to be used.

1.4.4.2 Address Maps and Translation

The MPC8240's processor bus supports memory-mapped accesses. The address space is divided between memory and PCI according to one of two allowable address maps—map A and map B. Note that the support of map A is provided for backward compatibility only. It is strongly recommended that new designs use map B because map A may not be supported in future devices.

An inbound and outbound PCI address translation mechanism is provided to support the use of the MPC8240 in agent mode. Note that address translation is supported only for agent mode; it is not supported when the MPC8240 is operating in host mode. Also note that since agent mode is supported only for address map B, address translation is supported only for address map B.

When the MPC8240 is configured to be a PCI agent, the amount of local memory visible to the system is programmable. In addition, it may be necessary to map the local memory to a different system memory address space. The address translation unit handles the mapping of both inbound and outbound transactions for these cases.

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1.4.4.3 Byte Ordering

The MPC8240 allows the processor to run in either big- or little-endian mode (except for the initial boot code which must run in big-endian mode).

1.4.4.4 PCI Agent Capability

In certain applications, the embedded system architecture dictates that the MPC8240 act as a peripheral processor. In this case, the peripheral logic must not act like a host bridge for the PCI bus. Instead it functions as a configurable device that is accessed by a host bridge. This capability allows multiple MPC8240 devices to coexist with other PCI peripheral devices on a single PCI bus. The MPC8240 has PCI 2.1- compliant configuration capabilities.

1.4.5 DMA Controller

The integrated DMA controller contains two independent units. Note that the DMA writing capability for local memory is available for DRAM and SDRAM, but writing is not available for the ROM/Port X interface. Each DMA unit is capable of performing the following types of transfers:

- PCI-to-local memory
- Local-to-PCI memory
- PCI-to-PCI memory
- Local-to-local memory

The DMA controller allows chaining through local memory-mapped chain descriptors. Transfers can be scatter-gathered and misaligned. Interrupts are provided on completed segment, chain, and error conditions.

1.4.6 Message Unit (MU)

Many embedded applications require handshake algorithms to pass control, status, and data information from one owner to another. This is made easier with doorbell and message registers. The MPC8240 has a message unit (MU) that implements doorbell and message registers as well as an I_2O interface. The MU has many conditions that can cause interrupts, and it uses the EPIC unit to signal external interrupts to the PCI interface and internal interrupts to the processor core.

1.4.6.1 Doorbell Registers

The MPC8240 MU contains one 32-bit inbound doorbell register and one 32-bit outbound doorbell register. The inbound doorbell register allows a remote processor to set a bit in the register from the PCI bus. This, in turn, generates an interrupt to the processor core.

The processor core can write to the outbound register, causing the outbound interrupt signal $\overline{\text{INTA}}$ to assert, thus interrupting a host processor on PCI. When $\overline{\text{INTA}}$ is generated, it can be cleared only by the host processor by writing ones to the bits that are set in the outbound doorbell register.

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1.4.6.2 Inbound and Outbound Message Registers

The MPC8240 contains two 32-bit inbound message registers and two 32-bit outbound message registers. The inbound registers allow a remote host or PCI master to write a 32-bit value, causing an interrupt to the processor core. The outbound registers allow the processor core to write an outbound message which causes the outbound interrupt signal $\overline{\text{INTA}}$ to assert.

1.4.6.3 Intelligent Input/Output Controller (I_2O)

The intelligent I/O specification is an open standard that defines an abstraction layer interface between the OS and subsystem drivers. Messages are passed between the message abstraction layer from one device to another.

The I_2O specification describes a system as being made up of host processors and input/output platforms (IOPs). The host processor is a single processor or a collection of processors working together to execute a homogenous operating system. An IOP consists of a processor, memory, and I/O interfaces. The IOP functions separately from other processors within the system to handle system I/O functions.

The I_2O controller of the MU enhances communication between hosts and IOPs within a system. There are two paths for messages—an inbound queue is used to transfer messages from a remote host or IOP to the processor core, and an outbound queue is used to transfer messages from the processor core to the remote host. Each queue is implemented as a pair of FIFOs. The inbound and outbound message queues each consists of a free_list FIFO and a post_list FIFO.

Messages are transferred between the host and the IOP using PCI memory-mapped registers. The MPC8240's I_2O controller facilitates moving the messages to and from the inbound and outbound registers and local IOP memory. Interrupts signal the host and IOP to indicate the arrival of new messages.

1.4.7 Inter-Integrated Circuit (I^2C) Controller

The I^2C serial interface has become an industry de facto standard for communicating with low-speed peripherals. Typically, it is used for system management functions and EEPROM support. The MPC8240 contains an I^2C controller with full master and slave functionality.

1.4.8 Embedded Programmable Interrupt Controller (EPIC)

The integrated embedded programmable interrupt controller (EPIC) of the MPC8240 reduces the overall component count in embedded applications. The EPIC unit is designed to collect external and internal hardware interrupts, prioritize them, and deliver them to the processor core.

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The module operates in one of three modes:

- In direct mode, five level- or edge-triggered interrupts can be connected directly to an MPC8240.
- In pass-through mode, interrupts detected at the IRQ0 input are passed directly to the processor core. Also in this case, interrupts generated by the I_2O, I^2C, and DMA controllers are passed to the $\overline{\text{L\_INT}}$ output signal.
- The MPC8240 provides a serial delivery mechanism when more than five external interrupt sources are needed. The serial mechanism allows for up to 16 interrupts to be serially scanned into the MPC8240. This mechanism increases the number of interrupts without increasing the number of pins.

The outbound interrupt request signal, $\overline{\text{L\_INT}}$, is used to signal interrupts to the host processor when the MPC8240 is configured for agent mode. The MPC8240 EPIC includes four programmable timers that can be used for system timing or for generating periodic interrupts.

1.4.9 Integrated PCI Bus and SDRAM Clock Generation

There are two PCI bus clocking solutions directed towards different system requirements. For systems where the MPC8240 is the host controller with a minimum number of clock loads, five clock fanout buffers are provided on-chip.

For systems requiring more clock fan out or where the MPC8240 is an agent device, external clock buffers may be used.

The MPC8240 provides an on-chip delay-locked loop (DLL) that supplies the external memory bus clock signals to SDRAM banks. The memory bus clock signals are of the same frequency and synchronous with the internal peripheral bus clock.

The four SDRAM clock outputs are generated by the internal DLL and can account for the trace length between SDRAM_SYNC_OUT signal and the SDRAM_SYNC_IN signal.

The MPC8240 requires a single clock input signal, PCI_SYNC_IN, which can be driven by the PCI clock fan-out buffers—specifically the PCI_SYNC_OUT output. PCI_SYNC_IN can also be driven by an external clock driver.

PCI_SYNC_IN is driven by the PCI bus frequency. An internal PLL, using PCI_SYNC_IN as a reference, generates an internal *sys-logic-clk* signal that is used for the internal logic. The peripheral bus clock frequency is configured at reset (by the MPC8240 PLL configuration signals (PLL_CFG[0:4])) to be a multiple of the PCI_SYNC_IN frequency.

The internal clocking of the processor core is generated from and synchronized to the internal peripheral bus clock by means of a second PLL. The core's PLL provides multiples of the internal processor core clock rates as specified in the *MPC8240 Hardware Specification.*

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1.5 Power Management

TheMPC8240 provides both automatic and program-controllable power reduction modes for progressive reduction of power consumption.

The MPC8240 has independent power management functionality for both the processor core and the peripheral logic.The MPC8240 provides hardware support for three levels of programmable power reduction for both the processor and the peripheral logic. Doze, nap, and sleep modes are invoked by register programming—HID0 in the case of the processor core and configuration registers in the case of the peripheral logic block.

The processor and peripheral logic blocks are both fully static, allowing internal logic states to be preserved during all power-saving modes. The following sections describe the programmable power modes.

1.5.1 Programmable Processor Power Management Modes

Table 1-1 summarizes the programmable power-saving modes for the processor core. These are very similar to those available in the MPC603e device.

Table 1-1. Programmable Processor Power Modes

PM Mode	Functioning Units	Activation Method	Full-Power Wake Up Method
Full power	All units active	—	—
Full power (with DPM)	Requested logic by demand	By instruction dispatch	—
Doze	Bus snooping Data cache as needed Decrementer timer	Controlled by software (write to HID0)	External asynchronous exceptions (assertion of $\overline{\text{SMI}}$ or $\overline{\text{int}}$), Decrementer exception Hard or soft reset Machine check exception ($\overline{\text{mcp}}$)
Nap	Decrementer timer	Controlled by software (write to HID0) and qualified with $\overline{\text{QACK}}$ from peripheral logic	External asynchronous exceptions (assertion of $\overline{\text{SMI}}$, or $\overline{\text{int}}$) Decrementer exception Negation of $\overline{\text{QACK}}$ by peripheral logic Hard or soft reset Machine check exception ($\overline{\text{mcp}}$)
Sleep	None	Controlled by software (write to HID0) and qualified with $\overline{\text{QACK}}$ from peripheral logic	External asynchronous exceptions (assertion of $\overline{\text{SMI}}$, or $\overline{\text{int}}$) Negation of $\overline{\text{QACK}}$ by peripheral logic Hard or soft reset Machine check exception ($\overline{\text{mcp}}$)

1.5.2 Programmable Peripheral Logic Power Management Modes

The following subsections describe the power management modes of the peripheral logic. Table 1-2 summarizes the programmable power-saving modes for the peripheral logic block.

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Table 1-2. Peripheral Logic Power Modes Summary

PM Mode	Functioning Units	Activation Method	Full-Power Wake Up Method
Full power	All units active	—	—
Doze	PCI address decoding and bus arbiter System RAM refreshing Processor bus request and NMI monitoring EPIC unit I^2C unit PLL	Controlled by software (write to PMCR1)	PCI access to memory Processor bus request Assertion of NMI[1] Interrupt to EPIC Hard Reset
Nap	PCI address decoding and bus arbiter System RAM refreshing Processor bus request and NMI monitoring EPIC unit I^2C unit PLL	Controlled by software (write to PMCR1) and processor core in nap or sleep mode ($\overline{\text{QREQ}}$ asserted)	PCI access to memory[2] Processor bus request Assertion of NMI[1] Interrupt to EPIC Hard Reset
Sleep	PCI bus arbiter System RAM refreshing (can be disabled) Processor bus request and NMI monitoring EPIC unit I^2C unit PLL (can be disabled)	Controlled by software (write to PMCR1) and processor core in nap or sleep mode ($\overline{\text{QREQ}}$ asserted)	Processor bus request Assertion of NMI[1] Interrupt to EPIC Hard Reset

1 Programmable option based on value of PICR1[MCP_EN] = 1

2 A PCI access to memory in nap mode does not cause $\overline{\text{QACK}}$ to negate; consequently, it does not wake up the processor core, and the processor core won't snoop this access. After servicing the PCI access, the peripheral logic automatically returns to the nap mode.

1.6 Programmable I/O Signals with Watchpoint

The MPC8240 programmable I/O facility allows the system designer to monitor the peripheral logic bus. Up to two watchpoints and their respective 4-bit countdown values can be programmed. When the programmed threshold of the selected watchpoint is reached, an external trigger signal is generated.

1.7 Debug Features

The MPC8240 includes the following debug features:

- Memory attribute and PCI attribute signals
- Debug address signals
- $\overline{\text{MIV}}$ signal: Marks valid address and data bus cycles on the memory bus.
- Error injection/capture on data path
- IEEE 1149.1 (JTAG)/test interface

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1.7.1 Memory Attribute and PCI Attribute Signals

The MPC8240 provides additional information corresponding to memory and PCI activity on several signals to assist with system debugging. The two types of attribute signals are described as follows:

- The memory attribute signals are associated with the memory interface and provide information concerning the source of the memory operation being performed by the MPC8240.
- The PCI attribute signals are associated with the PCI interface and provide information concerning the source of the PCI operation being performed by the MPC8240.

1.7.2 Memory Debug Address

When enabled, the debug address provides software disassemblers a simple way to reconstruct the 30-bit physical address for a memory bus transaction to DRAM and SDRAM, ROM, FLASH, or PortX. For DRAM or SDRAM, these 16 debug address signals are sampled with the column address and chip-selects. For ROMs, FLASH, and PortX devices, the debug address pins are sampled at the same time as the ROM address and can be used to recreate the 24-bit physical address in conjunction with ROM address. The granularity of the reconstructed physical address is limited by the bus width of the interface; double-words for 64-bit interfaces, words for 32-bit interfaces, and bytes for 8-bit interfaces.

1.7.3 Memory Interface Valid ($\overline{\text{MIV}}$)

The memory interface valid signal, $\overline{\text{MIV}}$, is asserted whenever FPM, EDO, SDRAM, FLASH, or ROM addresses or data are present on the external memory bus. It is intended to help reduce the number of bus cycles that logic analyzers must store in memory during a debug trace.

1.7.4 Error Injection/Capture on Data Path

The MPC8240 provides hardware to exercise and debug the ECC and parity logic by allowing the user to inject multi-bit stuck-at faults onto the peripheral logic or memory data/parity buses and to capture the data/parity output on receipt of an ECC or parity error.

1.7.5 IEEE 1149.1 (JTAG)/Test Interface

The processor core provides IEEE 1149.1 functions for facilitating board testing and debugging. The IEEE 1149.1 test interface provides a means for boundary-scan testing the processor core and the board to which it is attached.

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Chapter 2
Signal Descriptions and Clocking

This chapter provides descriptions of the MPC8240's external signals. It describes each signal's behavior when the signal is asserted and negated and when the signal is an input or an output.

NOTE:

A bar over a signal name indicates that the signal is active low—for example, $\overline{AS}$ (address strobe). Active-low signals are referred to as asserted (active) when they are low and negated when they are high. Signals that are not active low, such as NMI (nonmaskable interrupt), are referred to as asserted when they are high and negated when they are low.

Internal signals are depicted as lower case and in italics. For example, *sys_logic_clk* is an internal signal. These are referenced only as necessary for understanding of the external functionality of the device.

The chapter is organized into the following sections:

- Overview of signals and complete cross-reference for signals that serve multiple functions. Includes listing of output signal states at reset.
- Signal description section that provides a detailed description of each signal, listed by functional block
- A complete section on the operation of the many input and output clock signals on the MPC8240, and the interactions between these signals
- A listing of the reset configuration signals and the modes they define

2.1 Signal Overview

The MPC8240's signals are grouped as follows:

- PCI interface signals
- Memory interface signals
- EPIC control signals
- I^2C interface signals

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- System control, power management, and debug signals
- Test/configuration signals
- Clock signals

Figure 2-1 illustrates the external signals of the MPC8240, showing how the signals are grouped. Refer to the *MPC8240 Hardware Specification* for a pinout diagram showing actual pin numbers and a listing of all the electrical and mechanical specifications.

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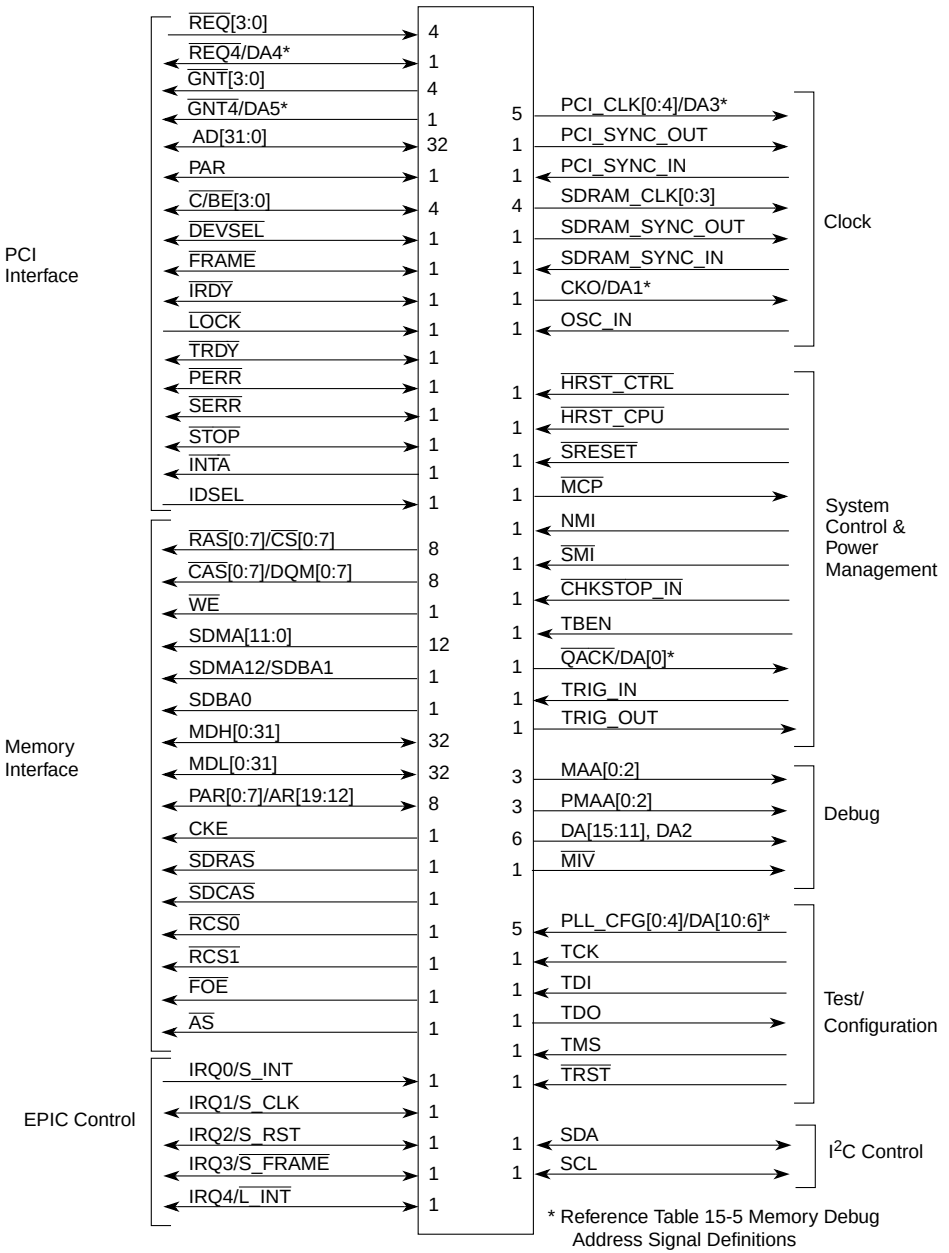

Figure 2-1. MPC8240 Signal Groupings

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2.1.1 Signal Cross Reference

The following sections are intended to provide a quick summary of signal functions. Table 2-1 provides an alphabetical cross-reference to the signals of the MPC8240. It details the signal name, interface, alternate functions, number of signals, whether the signal is an input, output, or bidirectional, and finally a pointer to the section in this chapter where the signal is described.

Table 2-1. MPC8240 Signal Cross Reference

Signal	Signal Name	Interface	Alternate Function (s)	Pins	I/O	Section #
AD[31:0]	Address/data	PCI	—	32	I/O	2.2.1.3
AR[19:12]	ROM address 19–12	Memory	PAR[0:7]	8	O	2.2.2.11
$\overline{\text{AS}}$[1]	Address strobe	Memory	—	1	O	2.2.2.18
$\overline{\text{CAS}}$[0:7]	Column address strobe 0–7	Memory	DQM[0:7]	8	O	2.2.2.2
$\overline{\text{C/BE}}$[3:0]	Command/byte enable	PCI	—	4	I/O	2.2.1.5
$\overline{\text{CHKSTOP\_IN}}$	Checkstop in	System Control	—	1	I	2.2.5.6
CKE[1]	SDRAM clock enable	Memory	—	1	O	2.2.2.12
CKO	Debug clock	Clock	DA1	1	O	2.2.7.8
$\overline{\text{CS}}$[0:7]	SDRAM chip select	Memory	$\overline{\text{RAS}}$[0:7]	8	O	2.2.2.3
DA[15:11], DA2	Debug addr [15:11, 2]	Debug	—	6	O	2.2.5.10.3
DA[10:6]	Debug addr [10:6]	Debug	PLL_CFG[0:4]	5	O	2.2.5.10.3
DA5 DA4 DA3 DA1 DA0	Debug addr 5 Debug addr 4 Debug addr 3 Debug addr 1 Debug addr 0	Debug	$\overline{\text{GNT4}}$ $\overline{\text{REQ4}}$ PCI_CLK4 CKO $\overline{\text{QACK}}$	5	O	2.2.5.10.3
$\overline{\text{DEVSEL}}$	Device select	PCI	—	1	I/O	2.2.1.6
DQM[0:7]	SDRAM data qualifier	Memory	$\overline{\text{CAS}}$[0:7]	8	O	2.2.2.4
$\overline{\text{FOE}}$[1]	Flash output enable	Memory	—	1	O	2.2.2.17
$\overline{\text{FRAME}}$	Frame	PCI	—	1	I/O	2.2.1.7
$\overline{\text{GNT}}$[3:0] $\overline{\text{GNT4}}$/DA5[1]	PCI bus grant	PCI	$\overline{\text{GNT0}}$: PCI bus request $\overline{\text{GNT4}}$: DA5	5	O	2.2.1.2
$\overline{\text{HRST\_CPU}}$	Hard reset (processor)	System Control	—	1	I	2.2.5.1.1
$\overline{\text{HRST\_CTRL}}$	Hard reset (peripheral logic)	System Control	—	1	I	2.2.5.1.2
IDSEL	ID select	PCI	—	1	I	2.2.1.15
$\overline{\text{INTA}}$	Interrupt request	PCI	—	1	O	2.2.1.14
$\overline{\text{IRDY}}$	Initiator ready	PCI	—	1	I/O	2.2.1.8
IRQ0	Interrupt 0	EPIC Control	S_INT	1	I	2.2.3.1
IRQ1	Interrupt 1	EPIC Control	S_CLK	1	I/O	2.2.3.1

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Table 2-1. MPC8240 Signal Cross Reference (Continued)

Signal	Signal Name	Interface	Alternate Function (s)	Pins	I/O	Section #
IRQ2	Interrupt 2	EPIC Control	S_RST	1	I/O	2.2.3.1
IRQ3	Interrupt 3	EPIC Control	$\overline{\text{S\_FRAME}}$	1	I/O	2.2.3.1
IRQ4	Interrupt 4	EPIC Control	$\overline{\text{L\_INT}}$	1	I/O	2.2.3.1
$\overline{\text{L\_INT}}$	Local interrupt	EPIC Control	IRQ4	1	I/O	2.2.3.3
$\overline{\text{LOCK}}$	Lock	PCI	—	1	I	2.2.1.9
MAA[0:2][1]	Memory addr attributes	Debug	—	3	O	2.2.5.10.1
$\overline{\text{MCP}}$[1]	Machine check	System Control	—	1	O	2.2.5.3
MDH[0:31]	Data bus high	Memory	—	32	I/O	2.2.2.9
MDL[0:31] MDL0[1]	Data bus low	Memory	—	32	I/O	2.2.2.9
$\overline{\text{MIV}}$	Memory interface valid	Debug	—	1	O	2.2.5.10.4
NMI	Nonmaskable interrupt	System Control	—	1	I	2.2.5.4
OSC_IN	System clock input	Clock	—	1	I	2.2.7.1
PAR	Parity	PCI	—	1	I/O	2.2.1.4
PAR[0:7]	Data parity 0–7	Memory	AR[19:12]	8	I/O	2.2.2.10
PCI_CLK[0:3] PCI_CLK4/DA3	PCI clock outputs	Clock	PCI_CLK4: DA3	5	O	2.2.7.2
PCI_SYNC_OUT	PCI clock output	Clock	—	1	O	2.2.7.3
PCI_SYNC_IN	PCI clock input	Clock	—	1	I	2.2.7.4
$\overline{\text{PERR}}$	Parity error	PCI	—	1	I/O	2.2.1.11
PLL_CFG[0:4][1]	PLL configuration	Test/Configuration	DA[10:6]	5	I	2.2.6.1
PMAA[0:2][1]	PCI addr. attributes	Debug	—	3	O	2.2.5.10.2
$\overline{\text{QACK}}$[1]	Quiesce acknowledge	Power Management	DA0	1	O	2.2.5.8
$\overline{\text{RAS}}$[0:7]	Row address strobe 0–7	Memory	$\overline{\text{CS}}$[0:7]	8	O	2.2.2.1
$\overline{\text{RCS0}}$[1]	ROM/bank 0 select	Memory	—	1	O	2.2.2.15
$\overline{\text{RCS1}}$	ROM/bank 1 select	Memory	—	1	O	2.2.2.16
$\overline{\text{REQ}}$[3:0] $\overline{\text{REQ4}}$/DA4	PCI bus request	PCI	$\overline{\text{REQ0}}$: PCI bus grant $\overline{\text{REQ4}}$: DA4	5	I I/O	2.2.1.1
S_CLK	Serial interrupt clock	EPIC Control	IRQ1	1	I/O	2.2.3.2.2
SCL	Serial clock	I^2C Control	—	1	I/O	2.2.4.2
SDA	Serial data	I^2C Control	—	1	I/O	2.2.4.1
SDBA0	SDRAM bank select 0	Memory	See Table 6-2	1	O	2.2.2.8
SDBA1	SDRAM bank select 1	Memory		1	O	2.2.2.8
$\overline{\text{SDCAS}}$	SDRAM column access strobe	Memory	—	1	O	2.2.2.14

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Table 2-1. MPC8240 Signal Cross Reference (Continued)

Signal	Signal Name	Interface	Alternate Function (s)	Pins	I/O	Section #
SDMA12	SDRAM address 12	Memory	See Table 6-2	1	O	2.2.2.7
SDMA[11:0]	SDRAM address 11–0	Memory		12	O	2.2.2.6
SDRAM_CLK[0:3]	SDRAM clock outputs	Clock	—	4	O	2.2.7.5
SDRAM_SYNC_OUT	SDRAM clock output	Clock	—	1	O	2.2.7.6
SDRAM_SYNC_IN	SDRAM feedback clock	Clock	—	1	I	2.2.7.7
$\overline{\text{SDRAS}}$	SDRAM row address strobe	Memory	—	1	O	2.2.2.13
$\overline{\text{SERR}}$	System error	PCI	—	1	I/O	2.2.1.12
$\overline{\text{S\_FRAME}}$	Serial interrupt frame	EPIC Control	IRQ3	1	I/O	2.2.3.2.4
S_INT	Serial interrupt stream	EPIC Control	IRQ0	1	I	2.2.3.2.1
$\overline{\text{SMI}}$	System management interrupt	System Control	—	1	I	2.2.5.5
S_RST	Serial interrupt reset	EPIC Control	IRQ2	1	I/O	2.2.3.2.3
$\overline{\text{SRESET}}$	Soft reset	System Control	—	1	I	2.2.5.2
$\overline{\text{STOP}}$	Stop	PCI	—	1	I/O	2.2.1.13
TBEN	Time base enable	System Control	—	1	I	2.2.5.7
TCK	JTAG test clock	Test	—	1	I	2.2.6.2
TDO	JTAG test data output	Test	—	1	O	2.2.6.4
TDI	JTAG test data Input	Test	—	1	I	2.2.6.3
TMS	JTAG test mode select	Test	—	1	I	2.2.6.5
$\overline{\text{TRDY}}$	Target ready	PCI	—	1	I/O	2.2.1.10
TRIG_IN	Watchpoint trigger in	System Control		1	I	2.2.5.9.1
TRIG_OUT	Watchpoint trigger out	System Control		1	O	2.2.5.9.2
$\overline{\text{TRST}}$	JTAG test reset	Test	—	1	I	2.2.6.6
$\overline{\text{WE}}$	Write enable	Memory	—	1	O	2.2.2.5

[1] The MPC8240 samples these signals at the negation of reset to determine the reset configuration. After they are sampled, they assume their normal functions. See Section 2.4, “Configuration Signals Sampled at Reset,” for more information about their function during reset.

2.1.2 Output Signal States during Reset

When a system reset is recognized (assertion of $\overline{\text{HRST\_CPU}}$ and $\overline{\text{HRST\_CTRL}}$), the MPC8240 aborts all current internal and external transactions, and releases all bidirectional I/O signals to a high-impedance state. See Section 13.2.1, “System Reset,” for a complete description of the reset functionality.

There are 19 signals that serve alternate functions as reset configuration input signals during system reset. Their default values and the interpretation of their voltage levels during reset are described in Section 2.4, “Configuration Signals Sampled at Reset.”

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During reset, the MPC8240 ignores most input signals (except for PCI_SYNC_IN and the reset configuration signals), and drives most of the output signals to an inactive state. Table 2-2 shows the states of the output-only signals that are not used as reset configuration signals during system reset.

Table 2-2. Output Signal States During System Reset

Interface	Signal	State During System Reset
PCI	$\overline{\text{GNT}}$[3:0] $\overline{\text{INTA}}$	High impedance
Memory	$\overline{\text{CAS}}$/DQM[0:7]	Driven high
	$\overline{\text{RAS}}$/$\overline{\text{CS}}$[0:7] $\overline{\text{RCS1}}$ $\overline{\text{SDRAS}}$ $\overline{\text{SDCAS}}$ $\overline{\text{WE}}$	Negated
	PAR[0:7]/AR[19:12], SDMA[11:0] SDMA12/SDBA1 SDBA0	High impedance
Clock	PCI_CLK[0:4] PCI_SYNC_OUT SDRAM_CLK[0:3] SDRAM_SYNC_OUT CKO	Driven
System control	TRIG_OUT	High impedance
Debug	DA[15:11], DA2	Driven high
Test/Configuration	TDO	Negated

2.2 Detailed Signal Descriptions

The following subsections describe the MPC8240 input and output signals, the meaning of their different states, and relative timing information for assertion and negation. In cases where signals serve multiple functions (and have multiple names), they are described individually for each function.

2.2.1 PCI Interface Signals

This section provides descriptions of the PCI interface signals on the MPC8240. Note that throughout this manual, signals and bits of the PCI interface are referenced in little-endian format. For more information on the operation of the MPC8240 PCI interface, see Chapter 7, “PCI Bus Interface.” Refer to the *PCI Local Bus Specification*, Revision 2.1 for a thorough description of the PCI local bus and specific signal-to-signal timing relationships for the PCI bus.

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2.2.1.1 PCI Bus Request ($\overline{\text{REQ}}$[4:0])—Input

The PCI bus request signals ($\overline{\text{REQ}}$[4:0]) are inputs on the MPC8240, and they have a different meaning depending on whether the MPC8240 PCI arbiter is enabled or disabled. The PCI $\overline{\text{REQ}}n$ signals are point-to-point, and every master has its own $\overline{\text{REQ}}n$ signal.

2.2.1.1.1 PCI Bus Request ($\overline{\text{REQ}}$[4:0])—Internal Arbiter Enabled

The MPC8240 PCI arbiter is enabled by a low value on the reset configuration pin MAA2 or by the setting of bit 15 of the PCI arbitration control register. In this case, the $\overline{\text{REQ}}$[4:0] signals are used in conjunction with the $\overline{\text{GNT}}$[4:0] signals as the arbiter for up to five PCI masters. Following is the state meaning for the $\overline{\text{REQ}}$[4:0] input signals in this case.

State Meaning Asserted—External devices are requesting control of the PCI bus. The MPC8240 acts on the requests as described in Section 7.2, "PCI Bus Arbitration."

Negated—Indicates that no external devices are requesting the use of the PCI bus.

2.2.1.1.2 PCI Bus Request ($\overline{\text{REQ}}$[4:0])—Internal Arbiter Disabled

The MPC8240 PCI arbiter is disabled by a high value on the reset configuration pin MAA2 or by the clearing of bit 15 of the PCI arbitration control register. In this case, the $\overline{\text{REQ0}}$ becomes the PCI bus grant input for the MPC8240, and it is asserted when the external arbiter is granting the use of the PCI bus to the MPC8240. Note that if the $\overline{\text{REQ0}}$ input signal is asserted prior to the need to run a PCI transaction, then the MPC8240 $\overline{\text{GNT0}}$ signal will not assert (the bus is parked) when a PCI transaction is to be run.

The $\overline{\text{REQ}}$[4:1] input signals are ignored when the internal arbiter is disabled. Following is the state meaning of the $\overline{\text{REQ0}}$ signal when the internal arbiter is disabled.

State Meaning Asserted—The $\overline{\text{REQ0}}$ signal indicates that the MPC8240 is granted control of the PCI bus. If $\overline{\text{REQ0}}$ is asserted before the MPC8240 has a transaction to perform (that is, the MPC8240 is parked), the MPC8240 drives AD[31:0], $\overline{\text{C/BE}}$[3:0], and PAR to stable (but meaningless) states until they are needed for a legitimate transaction.

Negated—$\overline{\text{REQ0}}$ is negated when the MPC8240 is not granted control of the PCI bus.

2.2.1.2 PCI Bus Grant ($\overline{\text{GNT}}$[4:0])—Output

The PCI bus grant ($\overline{\text{GNT}}$[4:0]) signals are outputs on the MPC8240 and they have a different meaning depending on whether the MPC8240 PCI arbiter is enabled or disabled. The PCI $\overline{\text{GNT}}n$ signals are point-to-point; every master has its own $\overline{\text{GNT}}n$ signal.

2.2.1.2.1 PCI Bus Grant ($\overline{\text{GNT}}$[4:0])—Internal Arbiter Enabled

The MPC8240 PCI arbiter is enabled by a low value on the reset configuration pin MAA2 or by the setting of bit 15 of the PCI arbitration control register. In this case, the $\overline{\text{GNT}}$[4:0]

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signals are used in conjunction with the $\overline{\text{REQ}}$[4:0] signals as the arbiter for up to five PCI masters. Following is the state meaning for the $\overline{\text{GNT}}$[4:0] input signals in this case.

State Meaning Asserted—The MPC8240 has granted control of the PCI bus to a requesting master, using the priority scheme described in Section 7.2, "PCI Bus Arbitration." The MPC8240 will assert only one $\overline{\text{GNT}}$*n* signal during any clock cycle.

Negated—Indicates that the MPC8240 has not granted control of the PCI bus and external devices may not initiate a PCI transaction.

2.2.1.2.2 PCI Bus Grant ($\overline{\text{GNT}}$[4:0])—Internal Arbiter Disabled

The MPC8240 PCI arbiter is disabled by a high value on the reset configuration pin MAA2 or by the clearing of bit 15 of the PCI arbitration control register. In this case, the $\overline{\text{GNT0}}$ becomes the PCI bus request output for the MPC8240 and is asserted when the MPC8240 needs to run a PCI transaction. If the $\overline{\text{REQ0}}$ input signal is asserted prior to the need to run a PCI transaction, then the $\overline{\text{GNT0}}$ signal will not assert (the bus is parked) when a PCI transaction is to be run. Following is the state meaning for the $\overline{\text{GNT}}$[4:0] input signals when the internal arbiter is disabled.

State Meaning Asserted—The MPC8240 asserts the $\overline{\text{GNT0}}$ signal as the PCI bus request output signal. $\overline{\text{GNT}}$[4:1] signals do not assert in this case.

Negated—The $\overline{\text{GNT}}$[4:1] signals are driven high (negated) in this mode. $\overline{\text{GNT0}}$ is negated when the MPC8240 is not requesting control of the PCI bus or the bus is parked on the MPC8240.

2.2.1.3 PCI Address/Data Bus (AD[31:0])

The PCI address/data bus (AD[31:0]) consists of 32 signals that are both input and output signals on the MPC8240.

2.2.1.3.1 Address/Data (AD[31:0])—Output

Following is the state meaning for AD[31:0] as outputs.

State Meaning Asserted/Negated—Represents the physical address during the address phase of a PCI transaction. During a data phase of a PCI transaction, AD[31:0] contain data being written.

The AD[7:0] signals define the least-significant byte and AD[31:24] the most-significant byte.

2.2.1.3.2 Address/Data (AD[31:0])—Input

Following is the state meaning for AD[31:0] as inputs.

State Meaning Asserted/Negated—Represents the address to be decoded as a check for device select during an address phase of a PCI transaction or data being received during a data phase of a PCI transaction.

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2.2.1.4 Parity (PAR)

The PCI parity (PAR) signal is both an input and output signal on the MPC8240. See Section 7.6.1, “PCI Parity,” for more information on PCI parity.

2.2.1.4.1 Parity (PAR)—Output

Following is the state meaning for PAR as an output signal.

State Meaning Asserted—This signal is driven by the MPC8240 to indicate odd parity across the AD[31:0] and $\overline{\text{C/BE}}$[3:0] signals (driven by the MPC8240) during the address and data phases of a transaction.

Negated—Indicates even parity across the AD[31:0] and $\overline{\text{C/BE}}$[3:0] signals driven by the MPC8240 during address and data phases.

2.2.1.4.2 Parity (PAR)—Input

Following is the state meaning for PAR as an input signal.

State Meaning Asserted—Indicates odd parity driven by another PCI master or the PCI target during read data phases.

Negated—Indicates even parity driven by another PCI master or the PCI target during read data phases.

2.2.1.5 Command/Byte Enable ($\overline{\text{C/BE}}$[3:0])

The four command/byte enable ($\overline{\text{C/BE}}$[3:0]) signals are both input and output signals on the MPC8240.

2.2.1.5.1 Command/Byte Enable ($\overline{\text{C/BE}}$[3:0])—Output

Following is the state meaning for $\overline{\text{C/BE}}$[3:0] as output signals.

State Meaning Asserted/Negated—During the address phase, $\overline{\text{C/BE}}$[3:0] define the bus command of the transaction initiated by the MPC8240 as a PCI master. Table 2-3 summarizes the PCI bus command encodings. See Section 7.3.2, “PCI Bus Commands,” for more detailed information on the bus commands.

During the data phase, $\overline{\text{C/BE}}$[3:0] are used as byte enables. Byte enables determine which byte lanes carry meaningful data. The $\overline{\text{C/BE0}}$ signal applies to the least-significant byte.

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Table 2-3. PCI Command Encodings

C/BE[3:0]	PCI Command
0000	Interrupt acknowledge
0001	Special cycle
0010	I/O read
0011	I/O write
0100	Reserved
0101	Reserved
0110	Memory read
0111	Memory write
1000	Reserved
1001	Reserved
1010	Configuration read
1011	Configuration write
1100	Memory read multiple
1101	Dual address cycle[1]
1110	Memory read line
1111	Memory write and invalidate

1 The MPC8240 does not generate this command or the reserved commands.

2.2.1.5.2 Command/Byte Enable (C/BE[3:0])—Input

Following is the state meaning for C/BE[3:0] as input signals.

State Meaning Asserted/Negated—During the address phase, C/BE[3:0] indicate the command that another master is sending. The MPC8240 uses the value on these signals (in addition to the address) to determine whether it is a target for a transaction. Table 2-3 summarizes the PCI bus command encodings. See Section 7.3.3, “Addressing,” for more information.

During the data phase, C/BE[3:0] indicate which byte lanes are valid.

2.2.1.6 Device Select (DEVSEL)

The device select (DEVSEL) signal is both an input and output on the MPC8240.

2.2.1.6.1 Device Select (DEVSEL)—Output

Following is the state meaning for DEVSEL as an output.

State Meaning Asserted—Indicates that the MPC8240 has decoded the address of a PCI transaction, and it is the target of the current access.

Negated—Indicates that the MPC8240 has decoded the address and is not the target of the current access.

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2.2.1.6.2 Device Select ($\overline{\text{DEVSEL}}$)—Input

Following is the state meaning for $\overline{\text{DEVSEL}}$ as an input signal.

State Meaning Asserted—Indicates that some PCI target (other than the MPC8240) has decoded its address as the target of the current access. This is useful to the MPC8240 when it is the initiator of a PCI transaction.

Negated—Indicates that no PCI target has been selected.

2.2.1.7 Frame ($\overline{\text{FRAME}}$)

The frame ($\overline{\text{FRAME}}$) signal is both an input and output on the MPC8240.

2.2.1.7.1 Frame ($\overline{\text{FRAME}}$)—Output

Following is the state meaning for $\overline{\text{FRAME}}$ as an output.

State Meaning Asserted—Indicates that the MPC8240, acting as a PCI master, is initiating a bus transaction. While $\overline{\text{FRAME}}$ is asserted, data transfers may continue.

Negated—If $\overline{\text{IRDY}}$ is asserted, indicates that the PCI transaction is in the final data phase. If $\overline{\text{IRDY}}$ is negated, it indicates that the PCI bus is idle.

2.2.1.7.2 Frame ($\overline{\text{FRAME}}$)—Input

Following is the state meaning for $\overline{\text{FRAME}}$ as an input signal.

State Meaning Asserted—Indicates that another PCI master is initiating a bus transaction and causes the MPC8240 to decode the address and the command signals to see if it is the target of the transaction.

Negated—Indicates that the transaction is in the final data phase or that the bus is idle.

2.2.1.8 Initiator Ready ($\overline{\text{IRDY}}$)

The initiator ready ($\overline{\text{IRDY}}$) signal is both an input and output on the MPC8240.

2.2.1.8.1 Initiator Ready ($\overline{\text{IRDY}}$)—Output

Following is the state meaning for $\overline{\text{IRDY}}$ as an output.

State Meaning Asserted—Indicates that the MPC8240, acting as a PCI master, can complete the current data phase of a PCI transaction. During a write, the MPC8240 asserts $\overline{\text{IRDY}}$ to indicate that valid data is present on AD[31:0]. During a read, the MPC8240 asserts $\overline{\text{IRDY}}$ to indicate that it is prepared to accept data.

Negated—Indicates that the PCI target needs to wait before the MPC8240, acting as a PCI master, can complete the current data phase. During a write, the MPC8240 negates $\overline{\text{IRDY}}$ to insert a wait

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cycle when it cannot provide valid data to the target. During a read, the MPC8240 negates $\overline{\text{IRDY}}$ to insert a wait cycle when it cannot accept data from the target.

2.2.1.8.2 Initiator Ready ($\overline{\text{IRDY}}$)—Input

Following is the state meaning for $\overline{\text{IRDY}}$ as an input signal.

State Meaning Asserted—Indicates another PCI master is able to complete the current data phase of a transaction.

Negated—If $\overline{\text{FRAME}}$ is asserted, it indicates a wait cycle from another master. This is used by the MPC8240 to insert wait cycles when it is a target of a PCI transaction. If $\overline{\text{FRAME}}$ is negated, it indicates the PCI bus is idle.

2.2.1.9 Lock ($\overline{\text{LOCK}}$)—Input

The lock ($\overline{\text{LOCK}}$) signal is an input on the MPC8240. See Section 7.5, “Exclusive Access,” for more information. Following is the state meaning for the $\overline{\text{LOCK}}$ input signal.

State Meaning Asserted—Indicates that a master is requesting exclusive access to memory, which may require multiple transactions to complete.

Negated—Indicates that a normal operation is occurring on the bus, or an access to a locked target is occurring.

2.2.1.10 Target Ready ($\overline{\text{TRDY}}$)

The target ready ($\overline{\text{TRDY}}$) signal is both an input and output signal on the MPC8240.

2.2.1.10.1 Target Ready ($\overline{\text{TRDY}}$)—Output

Following is the state meaning for $\overline{\text{TRDY}}$ as an output signal.

State Meaning Asserted—Indicates that the MPC8240, acting as a PCI target, can complete the current data phase of a PCI transaction. During a read, the MPC8240 asserts $\overline{\text{TRDY}}$ to indicate that valid data is present on AD[31:0]. During a write, the MPC8240 asserts $\overline{\text{TRDY}}$ to indicate that it is prepared to accept data.

Negated—Indicates that the PCI initiator needs to wait before the MPC8240, acting as a PCI target, can complete the current data phase. During a read, the MPC8240 negates $\overline{\text{TRDY}}$ to insert a wait cycle when it cannot provide valid data to the initiator. During a write, the MPC8240 negates $\overline{\text{TRDY}}$ to insert a wait cycle when it cannot accept data from the initiator.

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2.2.1.10.2 Target Ready ($\overline{\text{TRDY}}$)—Input

Following is the state meaning for $\overline{\text{TRDY}}$ as an input signal.

State Meaning Asserted—Indicates another PCI target is able to complete the current data phase of a transaction. If the MPC8240 is the initiator of the transaction, it latches the data (on a read) or cycles the data on a write.

Negated—Indicates a wait cycle needed by a target. If the MPC8240 is the initiator of the transaction, it waits to latch the data (on a read) or continues to drive the data (on a write).

2.2.1.11 Parity Error ($\overline{\text{PERR}}$)

The PCI parity error ($\overline{\text{PERR}}$) signal is both an input and output signal on the MPC8240. See Section 13.2.3.2, "Parity Error (PERR)," and Section 4.8.2, "Error Enabling and Detection Registers," for more information on how the MPC8240 is set up to report parity errors. The PCI initiator drives $\overline{\text{PERR}}$ on read operations; the PCI target drives $\overline{\text{PERR}}$ on write operations.

2.2.1.11.1 Parity Error ($\overline{\text{PERR}}$)—Output

Following is the state meaning for $\overline{\text{PERR}}$ as an output signal.

State Meaning Asserted—Indicates that the MPC8240, acting as a PCI agent, detected a data parity error.

Negated—Indicates no error.

2.2.1.11.2 Parity Error ($\overline{\text{PERR}}$)—Input

Following is the state meaning for $\overline{\text{PERR}}$ as an input signal.

State Meaning Asserted—Indicates that another PCI agent detected a data parity error while the MPC8240 was sourcing data (the MPC8240 was acting as the PCI initiator during a write, or was acting as the PCI target during a read).

Negated—Indicates no error.

2.2.1.12 System Error ($\overline{\text{SERR}}$)

The PCI system error ($\overline{\text{SERR}}$) signal is both an input and output signal on the MPC8240. It is an open-drain signal and can be driven by multiple devices on the PCI bus. Refer to Section 13.2.3.1, "System Error (SERR)," and Section 4.8.2, "Error Enabling and Detection Registers," for more information on how the MPC8240 drives and reports system errors.

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2.2.1.12.1 System Error ($\overline{\text{SERR}}$)—Output

Following is the state meaning for $\overline{\text{SERR}}$ as an output signal.

State Meaning Asserted—Indicates that an address parity error, a target-abort (when the MPC8240 is acting as the initiator), or some other system error (where the result is a catastrophic error) was detected.

Negated—Indicates no error.

2.2.1.12.2 System Error ($\overline{\text{SERR}}$)—Input

Following is the state meaning for $\overline{\text{SERR}}$ as an input signal.

State Meaning Asserted—Indicates that a target (other than the MPC8240) has detected a catastrophic error.

Negated—Indicates no error.

2.2.1.13 Stop ($\overline{\text{STOP}}$)

The stop ($\overline{\text{STOP}}$) signal is both an input and output signal on the MPC8240. Refer to Section 7.4.3.2, "Target-Initiated Termination," for more information on the use of the $\overline{\text{STOP}}$ signal.

2.2.1.13.1 Stop ($\overline{\text{STOP}}$)—Output

Following is the state meaning for $\overline{\text{STOP}}$ as an output signal.

State Meaning Asserted—Indicates that the MPC8240, acting as a PCI target, is requesting that the initiator stop the current transaction.

Negated—Indicates that the current transaction can continue.

2.2.1.13.2 Stop ($\overline{\text{STOP}}$)—Input

Following is the state meaning for $\overline{\text{STOP}}$ as an input signal.

State Meaning Asserted—Indicates that when the MPC8240 is acting as a PCI initiator, it is receiving a request from the target to stop the current transaction.

Negated—Indicates that the current transaction can continue.

2.2.1.14 Interrupt Request ($\overline{\text{INTA}}$)—Output

Following is the state meaning for $\overline{\text{INTA}}$. This signal is primarily used when the MPC8240 is programmed in agent mode.

State Meaning Asserted—Indicates that the MPC8240 is requesting an interrupt on the PCI bus. These interrupts are caused by the on-chip DMA controller and the message unit.

Negated—Indicates that the MPC8240 is not requesting an interrupt on the PCI bus.

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2.2.1.15 ID Select (IDSEL)—Input

Following is the state meaning for IDSEL. See Section 7.3.3.3, “Configuration Space Addressing,” for more information about the role of the IDSEL signal in PCI configuration transactions.

State Meaning Asserted—When the $\overline{\text{C/BE}}$[3:0] encoding is set to configuration read/write, IDSEL indicates that the PCI configuration registers on the MPC8240 are being accessed.

Negated—Indicates that there is no configuration access for this device in progress.

Note that the MPC8240 must not issue PCI configuration transactions to itself (that is, for PCI configuration transactions initiated by the MPC8240, its IDSEL signal must not be asserted). The MPC8240 must use the method described in Section 4.1, “Configuration Register Access,” to access its own configuration registers. If the MPC8240 is in host mode and other PCI agents do not need to access the MPC8240’s configuration space, then it is recommended that this signal be pulled down.

2.2.2 Memory Interface Signals

The memory interface supports either standard DRAMs, extended data out DRAMs (EDO DRAMs), or synchronous DRAMs (SDRAMs) and either standard ROM or Flash devices. Some of the memory interface signals perform different functions (and are described by an alternate name) depending on the RAM and ROM configurations. This section provides a brief description of the memory interface signals on the MPC8240, listed individually by both their primary and alternate names, describing the relevant function in each section. For more information on the operation of the memory interface, see Chapter 6, “MPC8240 Memory Interface.”

2.2.2.1 Row Address Strobe ($\overline{\text{RAS}}$[0:7])—Output

The eight row address strobe ($\overline{\text{RAS}}$[0:7]) signals are outputs on the MPC8240. Following are the state meaning and timing comments for the $\overline{\text{RAS}}n$ output signals.

State Meaning Asserted—Indicates that the memory row address is valid and selects one of the rows in the selected bank for DRAM memory.

Negated—Indicates DRAM precharge period.

Timing Comments Assertion—The MPC8240 asserts the $\overline{\text{RAS}}n$ signal to begin a memory cycle. All other memory interface signal timings are referenced to $\overline{\text{RAS}}n$.

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2.2.2.2 Column Address Strobe ($\overline{\text{CAS}}$[0:7])—Output

The eight column address strobe ($\overline{\text{CAS}}$[0:7]) signals are outputs on the MPC8240. $\overline{\text{CAS0}}$ connects to the most-significant byte select. $\overline{\text{CAS7}}$ connects to the least-significant byte select. When the MPC8240 is operating in 32-bit mode (see MCCR1[DBUS_SIZ[0:1]), the $\overline{\text{CAS}}$[0:3] signals are used. Following are the state meaning and timing comments for the $\overline{\text{CAS}}$*n* output signals.

State Meaning Asserted—Indicates that the DRAM (or EDO) column address is valid and selects one of the columns in the row.

Negated—For DRAMs, it indicates $\overline{\text{CAS}}$*n* precharge, and that the current DRAM data transfer has completed.
—or—
For EDO DRAMs, it indicates $\overline{\text{CAS}}$*n* precharge, and that the current data transfer completes in the first clock cycle of $\overline{\text{CAS}}$*n* precharge.

Timing Comments Assertion—The MPC8240 asserts $\overline{\text{CAS}}$*n* two to eight clock cycles after the assertion of $\overline{\text{RAS}}$*n* (depending on the setting of the MCCR3[RCD_2] parameter). See Section 6.3.5, “FPM or EDO DRAM Interface Timing,” for more information.

2.2.2.3 SDRAM Command Select ($\overline{\text{CS}}$[0:7])—Output

The eight SDRAM command select ($\overline{\text{CS}}$[0:7]) signals are output on the MPC8240. Following are the state meaning and timing comments for the $\overline{\text{CS}}$*n* output signals.

State Meaning Asserted—Selects an SDRAM bank to perform a memory operation.

Negated—Indicates no SDRAM action during the current cycle.

Timing Comments Assertion—The MPC8240 asserts the $\overline{\text{CS}}$*n* signal to begin a memory cycle. For SDRAM, $\overline{\text{CS}}$*n* is valid on the rising edge of the SDRAM_CLK[0:3] clock signals.

2.2.2.4 SDRAM Data Input/Output Mask (DQM[0:7])—Output

The eight SDRAM data input/output mask (DQM[0:7]) signals are outputs on the MPC8240. Following are the state meaning and timing comments for the DQM*n* output signals. DQM0 connects to the most significant byte select, and DQM7 connects to the least significant byte select. Note that parity memory can be connected to any DQM*n* signal.

State Meaning Asserted—Prevents writing to SDRAM. Note that the DQM*n* signals are active-high for SDRAM. DQM*n* is part of the SDRAM command encoding. See Section 6.2, “SDRAM Interface Operation,” for more information.

Negated—Allows a read or write operation to SDRAM.

Timing Comments Assertion—For SDRAM, DQM*n* is valid on the rising edge of the SDRAM_CLK[0:3] clock signals during read or write cycles.

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2.2.2.5 Write Enable ($\overline{WE}$)—Output

The write enable ($\overline{WE}$) signal is an output on the MPC8240. For SDRAM, $\overline{WE}$ is part of the SDRAM command encoding. See Section 6.2, "SDRAM Interface Operation," for more information. Following are the state meaning and timing comments for the $\overline{WE}$ output signal for DRAM, ECO and Flash writes.

State Meaning Asserted—Enables writing to DRAM, EDO, or Flash.

Negated—No DRAM, EDO, or Flash write operation is pending.

Timing Comments Assertion—For DRAM, the MPC8240 asserts $\overline{WE}$ concurrent with the column address and prior to $\overline{CAS}n$. For SDRAM, the MPC8240 asserts $\overline{WE}$ concurrent with $\overline{SDCAS}$ for write operations.

2.2.2.6 SDRAM Address (SDMA[11:0])—Output

The SDMA[11:0] signals carry 12 of the address bits for the memory interface. For (S)DRAMs, they correspond to the row and column address bits.

State Meaning Asserted/Negated—Contain different portions of the address depending on the size of memory in use, the type of memory in use (DRAM, SDRAM, ROM or Flash) and the phase of the transaction. See Section 6.2.2, "SDRAM Address Multiplexing", for a complete description of the mapping of these signals in all cases.

Timing Comments Assertion—For DRAM, the row address is considered valid on the assertion of $\overline{RAS}n$, and the column address is valid on the assertion of $\overline{CAS}n$. For SDRAM, the row address is valid on the rising edge of SDRAM_CLK[0:3] clock signals when $\overline{CS}n$ is asserted and the column address is valid on the rising edge of SDRAM_CLK[0:3] when DQM*n* is asserted. For ROM and Flash, the address is valid with the assertion of $\overline{RCS0}$.

2.2.2.7 SDRAM Address 12 (SDMA12)—Output

The SDMA12 signal is similar to SDMA[11:0] in that it corresponds to different row or column address bits, depending on the memory in use.

State Meaning Asserted/Negated—See Section 6.2.2, "SDRAM Address Multiplexing," for a complete description of the mapping of this signal in all cases.

Timing Comments Assertion/Negation—The same as SDMA[11:0].

2.2.2.8 SDRAM Internal Bank Select 0–1 (SDBA0, SDBA1)—Output

The SDBA[0:1] signals are similar to SDMA[11:0] in that they correspond to different row or column address bits, depending on the memory in use. However, they are only used for the SDRAM interface. Note that SDBA1 is multiplexed with the SDMA12 signal.

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State Meaning Asserted/Negated—Selects the SDRAM internal bank to be activated during the row address phase and selects the SDRAM internal bank for the read or write operation during the column address phase of the memory access. See Section 6.2.2, "SDRAM Address Multiplexing," for a complete description of the mapping of these signals in all cases.

Timing Comments Assertion/Negation—The row address is valid on the rising edge of SDRAM_CLK[0:3] clock signals when $\overline{CS}n$ is asserted and the column address is valid on the rising edge of SDRAM_CLK[0:3] when DQM*n* is asserted.

2.2.2.9 Memory Data Bus (MDH[0:31], MDL[0:31])

The memory data bus (MDH[0:31], MDL[0:31]) consists of 64 signals that are both input and output signals on the MPC8240. The data bus is comprised of two halves—data bus high (MDH[0:31]) and data bus low (MDL[0:31]).

The MPC8240 can also be configured to operate with a 32-bit data bus on the memory interface by driving the reset configuration signal MDL0 low during reset. When the MPC8240 is configured with a 32-bit data bus, the bus operates in the same way as when configured with a 64-bit data bus, with the exception that only MDH[0:31] is used, and MDL[0:31] can be left floating. For more information on other data bus sizes available for the ROM/Flash/Port X interfaces, see Chapter 6, "MPC8240 Memory Interface."

Table 2-4 specifies the byte lane assignments (and data parity signal correspondence) for the transfer of an aligned double word in both 64- and 32-bit modes.

Table 2-4. Memory Data Bus Byte Lane Assignments

Data Bus Signals	Byte Lane	
	64-Bit Mode	32-Bit Mode
MDH[0:7]	0 (MSB)	0 (MSB), 4
MDH[8:15]	1	1, 5
MDH[16:23]	2	2, 6
MDH[24:31]	3	3, 7 (LSB)
MDL[0:7]	4	x
MDL[8:15]	5	x
MDL[16:23]	6	x
MDL[24:31]	7 (LSB)	x

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2.2.2.9.1 Memory Data Bus (MDH[0:31], MDL[0:31])—Output

Following are the state meaning and timing comments for the memory data bus as output signals.

State Meaning Asserted/Negated—Represents the value of data being driven by the MPC8240.

Timing Comments Assertion/Negation—For DRAM accesses, the data bus signals are valid when $\overline{\text{CAS}}$[0:7] and $\overline{\text{WE}}$ are asserted. For SDRAM, the data bus signals are valid on the next rising edge of SDRAM_CLK[0:3] after DQM[0:7] is asserted for a write command. For ROM/Flash memory and Port X, the data bus signals are valid on the assertion of $\overline{\text{RCS0}}$.

2.2.2.9.2 Memory Data Bus (MDH[0:31], MDL[0:31])—Input

Following are the state meaning and timing comments for the data bus as input signals. Note that MDL0 is a reset configuration input signal.

State Meaning Asserted/Negated—Represents the value of data being driven by the memory subsystem on a read.

Timing Comments Assertion/Negation—For a memory read transaction, the data bus signals are valid at a time dependent on the memory interface configuration parameters. Refer to Chapter 4, “Configuration Registers,” and Chapter 6, “MPC8240 Memory Interface,” for more information.

2.2.2.10 Data Parity/ECC (PAR[0:7])

The eight data parity/ECC (PAR[0:7]) signals are both input and output signals on the MPC8240.

2.2.2.10.1 Data Parity (PAR[0:7])—Output

Following are the state meaning and timing comments for PAR[0:7] as output signals.

State Meaning Asserted/Negated—Represents the byte parity or ECC bits being written to memory (PAR0 is the most-significant parity bit and corresponds to byte lane 0 which is selected by $\overline{\text{CAS0}}$ or DQM0). The data parity signals are asserted or negated as appropriate to provide odd parity (including the parity bit) or ECC.

Timing Comments Assertion/Negation—PAR[0:7] are valid concurrent with MDH[0:31] and MDL[0:31].

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2.2.2.10.2 Data Parity (PAR[0:7])—Input

Following are the state meaning and timing comments for PAR[0:7] as input signals.

State Meaning Asserted/Negated—Represents the byte parity or ECC bits being read from memory (PAR0 is the most-significant parity bit and corresponds to byte lane 0 which is selected by $\overline{\text{CAS0}}$ or DQM0).

Timing Comments Assertion/Negation—PAR[0:7] are valid concurrent with MDH[0:31] and MDL[0:31].

2.2.2.11 ROM Address 19:12 (AR[19:12])—Output

The ROM address 19–12 (AR[19:12]) signals are output signals only for the ROM address function. Note that these signals are both input and output signals for the memory parity function (PAR[0:7]). Following are the state meaning and timing comments for AR[19:12] as output signals.

State Meaning Asserted/Negated—Represents bits 19–12 of the ROM/Flash address. The other ROM address bits are provided by AR[10:0] as shown in Section 6.4.1, “ROM/Flash Address Multiplexing.”

Timing Comments Assertion/Negation—The ROM address is valid on assertion of $\overline{\text{RCS0}}$ or $\overline{\text{RCS1}}$.

2.2.2.12 SDRAM Clock Enable (CKE)—Output

The SDRAM clock enable (CKE) signal is an output on the MPC8240 (and is also used as a reset configuration input signal). CKE is part of the SDRAM command encoding. See Section 6.2, “SDRAM Interface Operation,” for more information. Following are the state meaning and timing comments for the CKE output signal.

State Meaning Asserted—Enables the internal clock circuit of the SDRAM memory device.

Negated—Disables the internal clock circuit of the SDRAM memory device.

Timing Comments Assertion—CKE is valid on the rising edge of the SDRAM_CLK[0:3] clock signals. See Section 6.2, “SDRAM Interface Operation,” for more information.

2.2.2.13 SDRAM Row Address Strobe ($\overline{\text{SDRAS}}$)—Output

The SDRAM row address strobe ($\overline{\text{SDRAS}}$) signal is an output on the MPC8240. Following are the state meaning and timing comments for the $\overline{\text{SDRAS}}$ output signal.

State Meaning Asserted/Negated—$\overline{\text{SDRAS}}$ is part of the SDRAM command encoding and is used for SDRAM bank selection during read or write operations. See Section 6.2, “SDRAM Interface Operation,” for more information.

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Timing Comments Assertion—$\overline{\text{SDRAS}}$ is valid on the rising edge of the SDRAM clock when a $\overline{\text{CS}}n$ signal is asserted.

2.2.2.14 SDRAM Column Address Strobe ($\overline{\text{SDCAS}}$)—Output

The SDRAM column address strobe ($\overline{\text{SDCAS}}$) signal is an output on the MPC8240. Following are the state meaning and timing comments for the $\overline{\text{SDCAS}}$ output signal.

State Meaning Asserted—$\overline{\text{SDCAS}}$ is part of the SDRAM command encoding and is used for SDRAM column selection during read or write operations. See Section 6.2, "SDRAM Interface Operation," for more information.

Negated—$\overline{\text{SDCAS}}$ is part of SDRAM command encoding used for SDRAM column selection during read or write operations.

Timing Comments Assertion—For SDRAM, $\overline{\text{SDCAS}}$ is valid on the rising edge of the SDRAM clock when a $\overline{\text{CS}}n$ signal is asserted.

2.2.2.15 ROM Bank 0 Select ($\overline{\text{RCS0}}$)—Output

The ROM bank0 select ($\overline{\text{RCS0}}$) signal is an output on the MPC8240 (and a reset configuration input signal). Following are the state meaning and timing comments for the $\overline{\text{RCS0}}$ output signal.

State Meaning Asserted—Selects ROM bank 0 for a read access or Flash bank 0 for a read or write access.

Negated—Deselects bank 0, indicating no pending memory access to ROM/Flash.

Timing Comments Assertion—The MPC8240 asserts $\overline{\text{RCS0}}$ at the start of a ROM/Flash access cycle.

Negation—Controlled by the ROMFAL and ROMNAL parameters of the MCCR1 register.

2.2.2.16 ROM Bank 1 Select ($\overline{\text{RCS1}}$)—Output

The ROM bank 1 select ($\overline{\text{RCS1}}$) signal is an output on the MPC8240. Following are the state meaning and timing comments for the $\overline{\text{RCS1}}$ output signal.

State Meaning Asserted—Selects ROM bank 1 for a read access or Flash bank 1 for a read or write access.

Negated—Deselects bank 1, indicating no pending memory access to ROM/Flash.

Timing Comments Assertion—The MPC8240 asserts $\overline{\text{RCS1}}$ at the start of a ROM/Flash access cycle.

Negation—Controlled by the ROMFAL and ROMNAL parameters of the MCCR1 register.

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2.2.2.17 Flash Output Enable ($\overline{\text{FOE}}$)—Output

The Flash output enable ($\overline{\text{FOE}}$) signal is an output on the MPC8240 (and a reset configuration input signal). Following are the state meaning and timing comments for the $\overline{\text{FOE}}$ output signal.

State Meaning Asserted—Enables Flash output for the current read access.

Negated—Indicates that there is currently no read access to Flash.

Note that the $\overline{\text{FOE}}$ signal provides no indication of any write operation(s) to Flash.

Timing Comments Assertion—The MPC8240 asserts $\overline{\text{FOE}}$ at the start of the Flash read cycle.

Negation—Controlled by the ROMFAL and ROMNAL parameters of the MCCR1 register.

2.2.2.18 Address Strobe ($\overline{\text{AS}}$)—Output

The $\overline{\text{AS}}$ output signal is used as a user-defined timing signal for the Port X interface. The assertion and pulse width are fully programmable with the ASFALL and ASRISE parameters in the MCCR2 register. $\overline{\text{AS}}$ is also a reset configuration input signal.

State Meaning Asserted—Programmable number of clocks (ASFALL) from the assertion of $\overline{\text{RCS0}}$ or $\overline{\text{RCS1}}$.

Negated—Programmable number of clocks (ASRISE) from the assertion of $\overline{\text{AS}}$.

2.2.3 EPIC Control Signals

There are five EPIC interrupt control signals that have dual functions. The signals serve as five distinct incoming interrupt requests (IRQ[0:4]) when the EPIC unit is in discrete interrupt mode (defined by GCR[M] = 1 and EICR[SIE] = 0). When the EPIC unit is in the serial interrupt mode (GCR[M] = 1 and EICR[SIE] = 1) or pass-through mode (GCR[M] = 0), each signal takes on an alternate function. The protocol for the various modes of the EPIC unit are described in Chapter 11, “Embedded Programmable Interrupt Controller (EPIC) Unit.”

2.2.3.1 Discrete Interrupt 0:4 (IRQ[0:4])—Input

Following is the state meaning for the IRQ[0:4] signals (discrete interrupt mode). The polarity and sense of each of these signals is programmable. All of these inputs can be driven completely asynchronously. In pass-through mode, interrupts from external source IRQ0 are passed directly to the processor.

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State Meaning Asserted/Negated—When the interrupt signal is asserted (according to the programmed polarity), the priority is checked by the EPIC unit, and the interrupt is conditionally passed to the processor as described in Chapter 11, "Embedded Programmable Interrupt Controller (EPIC) Unit."

2.2.3.2 Serial Interrupt Mode Signals

The serial interrupt mode provides for up to 16 interrupts to be serially clocked in through the S_INT signal. The relative timing for these signals is described in Section 11.6.2, "Serial Interrupt Timing Protocol."

2.2.3.2.1 Serial Interrupt Stream (S_INT)—Input

This signal represents the incoming interrupt stream in serial interrupt mode.

State Meaning Asserted/Negated—Represents the interrupts for up to 16 external interrupt sources with individually programmable sense and polarity. These interrupts are clocked in to the MPC8240 by the S_CLK signal.

2.2.3.2.2 Serial Interrupt Clock (S_CLK)—Output

This output serves as the serial clock that the external interrupt source must use for driving the 16 interrupts onto the S_INT signal.

State Meaning Asserted/Negated—The frequency of this clock signal is programmed in the serial interrupt configuration register.

2.2.3.2.3 Serial Interrupt Reset (S_RST)—Output

Following is the state meaning of the S_RST signal.

State Meaning Asserted/Negated—S_RST is asserted only once for two S_CLK cycles when the EPIC is programmed to the serial interrupt mode.

2.2.3.2.4 Serial Interrupt Frame ($\overline{\text{S\_FRAME}}$)—Output

Following is the state meaning of the $\overline{\text{S\_FRAME}}$ signal.

State Meaning Asserted/Negated—Synchronizes the serial interrupt sampling to interrupt source 00.

2.2.3.3 Local Interrupt ($\overline{\text{L\_INT}}$)—Output

Following is the state meaning of the $\overline{\text{L\_INT}}$ signal.

State Meaning Asserted/Negated—When the EPIC is programmed in pass-through mode, this output reflects the raw interrupts generated by the on-chip MU, I^2C, and DMA controllers.

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2.2.4 I²C Interface Control Signals

These two signals serve as a communication interconnect with other devices. All devices connected to these two signals must have open-drain or open-collector outputs. The logic AND function is performed on both of these signals with external pull-up resistors. Refer to the *MPC8240 Hardware Specification* for the electrical characteristics of these signals.

Chapter 10, "I²C Interface," has a complete description of the I²C protocol and the relative timings of the I²C signals.

2.2.4.1 Serial Data (SDA)

This signal is an input when the MPC8240 is in a receiving mode and an output when it is transmitting (as an I²C master or a slave).

2.2.4.1.1 Serial Data (SDA)—Output

Following is the state meaning of the SDA output signal when the MPC8240 is transmitting (as an I²C master or a slave).

State Meaning Asserted/Negated—Used to drive the data.

2.2.4.1.2 Serial Data (SDA)—Input

Following is the state meaning of the SDA input signal when the MPC8240 is receiving data.

State Meaning Asserted/Negated—Used to receive data from other devices. The bus is assumed to be busy when SDA is detected low.

2.2.4.2 Serial Clock (SCL)

This signal is an input when the MPC8240 is programmed as an I²C slave and an output when programmed as an I²C master.

2.2.4.2.1 Serial Clock (SCL)—Output

Following is the state meaning of the SCL output signal when the MPC8240 is an I²C master.

State Meaning Asserted/Negated—Driven along with SDA as the clock for the data.

2.2.4.2.2 Serial Clock (SCL)—Input

Following is the state meaning of the SCL output signal when the MPC8240 is an I²C slave.

State Meaning Asserted/Negated—The I²C unit uses this signal to synchronize incoming data on SDA. The bus is assumed to be busy when this signal is detected low.

2.2.5 System Control and Power Management Signals

The following sections describe the system control and power management signals of the MPC8240.

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2.2.5.1 Hard Reset

The two hard reset signals on the MPC8240 ($\overline{\text{HRST\_CPU}}$ and $\overline{\text{HRST\_CTRL}}$) must be asserted and negated together to guarantee normal operation. Together, $\overline{\text{HRST\_CPU}}$ and $\overline{\text{HRST\_CTRL}}$ cause the MPC8240 to abort all current internal and external transactions, and set all registers to their default values. Although $\overline{\text{HRST\_CPU}}$ and $\overline{\text{HRST\_CTRL}}$ must be asserted together, they may be asserted completely asynchronously with respect to all other signals. See Section 13.2.1, “System Reset,” for a complete description of the reset functionality.

2.2.5.1.1 Hard Reset (Processor) ($\overline{\text{HRST\_CPU}}$)—Input

The following describes the state meaning and timing for the $\overline{\text{HRST\_CPU}}$ input signal.

State Meaning Asserted/Negated—See Section 2.1.2, “Output Signal States during Reset,” and Section 2.4, “Configuration Signals Sampled at Reset,” for more information on the interpretation of the other MPC8240 signals during reset.

Timing Comments Assertion/Negation—See the *MPC8240Hardware Specification* for specific timing information of these signals and the reset configuration signals.

2.2.5.1.2 Hard Reset (Peripheral Logic) ($\overline{\text{HRST\_CTRL}}$)—Input

The following describes the state meaning and timing for the $\overline{\text{HRST\_CTRL}}$ input signal.

State Meaning Asserted/Negated—See Section 2.1.2, “Output Signal States during Reset”, and Section 2.4, “Configuration Signals Sampled at Reset,” for more information on the interpretation of the other MPC8240 signals during reset.

Timing Comments Assertion/Negation—See the *MPC8240 Hardware Specification* for specific timing information of these signals and the reset configuration signals.

2.2.5.2 Soft Reset ($\overline{\text{SRESET}}$)—Input

The assertion of the soft reset input signal causes the same actions as the assertion of the internal $\overline{sreset}$ signal by the EPIC unit. A soft reset is recoverable, provided that in attempting to reach a recoverable state, the processor does not encounter a machine check condition. A soft reset exception is third in priority, following a hard reset and machine check.

State Meaning Asserted/Negated—When $\overline{\text{SRESET}}$ is asserted, the processor core attempts to reach a recoverable state by allowing the next instruction to either complete or cause an exception, blocking the completion of subsequent instructions, and allowing the completed store queue to drain. Unlike a hard reset, no registers or latches are initialized; however, the instruction cache is disabled (HID0[ICE] = 0].

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Timing Comments Assertion—May occur at any time, asynchronous to any clock.
Negation—Must be asserted for at least 2 *sys_logic_clk* cycles. After $\overline{\text{SRESET}}$ is negated, the processor vectors to the system reset vector.

2.2.5.3 Machine Check ($\overline{\text{MCP}}$)—Output

The $\overline{\text{MCP}}$ signal is driven by the MPC8240 when a machine check error is generated by any of the conditions described in Chapter 13, "Error Handling," for generating the internal $\overline{mcp}$ signal. The assertion of $\overline{\text{MCP}}$ depends upon whether the error handling registers of the MPC8240 are set to report the specific error. Additionally, the programmable parameter PICR1[MCP_EN] is used to enable or disable the assertion of $\overline{\text{MCP}}$ by the MPC8240 for all error conditions. $\overline{\text{MCP}}$ is also used as a reset configuration input signal.

State Meaning Asserted—Reflects the state of the internal $\overline{mcp}$ signal. Indicates that a reportable error condition, as defined in Chapter 13, "Error Handling," has occurred. The current transaction may or may not be aborted depending upon the software configuration. Assertion of $\overline{mcp}$ causes the processor core to conditionally take a machine check exception or enter the checkstop state based on the setting of the MSR[ME] bit in the processor core.

Negated—There is no $\overline{mcp}$ being reported to the processor core.

Timing Comments Assertion—$\overline{mcp}$ may be asserted to the processor core in any cycle, so the same timing applies to $\overline{\text{MCP}}$.

Negation—The MPC8240 holds $\overline{mcp}$ asserted until the processor core has taken the exception. The MPC8240 decodes a machine check acknowledge cycle by detecting processor reads from the two possible machine check exception addresses at 0x0000_0200–0x0000_0207 and 0xFFF0_0200–0xFFF0_0207 and then negates $\overline{mcp}$. This timing also applies to $\overline{\text{MCP}}$.

High impedance—If the PMCR2[SHARED_MCP] bit is set, the $\overline{\text{MCP}}$ signal is placed in high impedance when there is no error to report.

2.2.5.4 Nonmaskable Interrupt (NMI)—Input

The nonmaskable interrupt (NMI) signal is an input on the MPC8240. Following are the state meaning and timing comments for the NMI input signal. See Chapter 13, "Error Handling," for more information.

State Meaning Asserted—Indicates that the MPC8240 should signal a machine check interrupt ($\overline{mcp}$) to the processor core.

Negated—No NMI reported.

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Timing Comments Assertion—NMI may occur at any time, asynchronously.

Negation—Should not occur until after the interrupt is taken. (interrupt source assumed to be cleared by software in the interrupt handler routine).

2.2.5.5 System Management Interrupt ($\overline{\text{SMI}}$)—Input

Following are the state meaning and timing comments for $\overline{\text{SMI}}$.

State Meaning Asserted—The $\overline{\text{SMI}}$ input signal is level-sensitive, and causes exception processing for a system management interrupt when $\overline{\text{SMI}}$ is asserted and MSR[EE] is set.

Negated—Indicates that normal operation should proceed.

Timing Comments Assertion—May occur at any time and may be asserted asynchronously to the input clocks.

Negation—Should not occur until the interrupt is taken.

2.2.5.6 Checkstop In ($\overline{\text{CHKSTOP\_IN}}$)—Input

Following are the state meaning and timing comments for the $\overline{\text{CHKSTOP\_IN}}$ signal.

State Meaning Asserted—Indicates that the MPC8240 processor core must terminate operation by internally gating off all clocks, and releasing all processor-related outputs to the high-impedance state.

Negated—Indicates that normal operation should proceed.

Timing Comments Assertion—May occur at any time and may be asserted asynchronously to the input clocks.

Negation—Must remain asserted until the system has been reset with a hard reset.

2.2.5.7 Time Base Enable (TBEN)—Input

Following are the state meaning and timing comments for TBEN.

State Meaning Asserted—Indicates that the time base and decrementer should continue clocking. This input is essentially a count enable control for the time base counter and the decrementer.

Negated—Indicates that the time base and decrementer should stop clocking.

Timing Comments Assertion/Negation—May occur on any cycle.

2.2.5.8 Quiesce Acknowledge ($\overline{\text{QACK}}$)—Output

The quiesce acknowledge ($\overline{\text{QACK}}$) signal is an output on the MPC8240.It is also a reset configuration input signal. See Chapter 14, “Power Management,” for more information

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about the power management signals. Following are the state meaning and timing comments for the $\overline{\text{QACK}}$ output signal.

State Meaning Asserted—Indicates that the processor core and peripheral logic are in either nap or sleep mode.

Negated—Indicates that the processor core and peripheral logic are not in nap or sleep mode.

2.2.5.9 Watchpoint Trigger Signals

There is one watchpoint trigger input and one watchpoint trigger output signal that together provide a programmable output signal and control of the watchpoint facility. See Chapter 16, "Programmable I/O and Watchpoint," for more information about the watchpoint facility.

2.2.5.9.1 Watchpoint Trigger In (TRIG_IN)—Input

The watchpoint trigger in (TRIG_IN) signal is an input on the MPC8240. Following are the state meaning and timing comments for the TRIG_IN signal. Note that TRIG_IN is an active-high (rising-edge triggered) signal.

State Meaning Asserted—May cause the MPC8240 to exit the HOLD state, or causes the value of the WP_RUN bit in the WP_CONTROL register to toggle (turning the watchpoint facility on or off). See Chapter 16, "Programmable I/O and Watchpoint," for more information.

Negated—No action taken.

Timing Comments Assertion/Negation—The MPC8240 interprets TRIG_IN as asserted on detection of the rising edge of TRIG_IN. Only required to be asserted for a single clock cycle.

2.2.5.9.2 Watchpoint Trigger Out (TRIG_OUT)—Output

The watchpoint trigger out (TRIG_OUT) signal is an output on the MPC8240. Following are the state meaning and timing comments for the TRIG_OUT signal. Note that the active sense of TRIG_OUT is controlled by the setting of WP_CONTROL[WP_TRIG].

State Meaning Asserted—Indicates that a final watchpoint match has occurred, as defined in the WP_MODE field of the WP_CONTROL register.

Negated—No final watchpoint match condition.

Timing Comments Assertion/Negation—Asserted until TRIG_IN is asserted, unless the WP_TRIG_HOLD parameter in the WP_CONTROL register is cleared. Then TRIG_OUT is asserted for a single clock cycle.

2.2.5.10 Debug Signals

The following sections describe the debug signals used by the MPC8240 in various debug modes. See Chapter 15, "Debug Features," for more details and timing information on the debug signals.

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2.2.5.10.1 Memory Address Attributes (MAA[0:2])—Output

The memory attribute signals are associated with the memory interface and provide information about the source of the memory operation being performed by the MPC8240. They are also reset configuration input signals.

State Meaning Asserted/Negated—These signals are encoded to provide more detailed information about a memory transaction. See Section 15.2.1, "Memory Address Attribute Signals (MAA[0:2])," for a table showing these encodings.

Timing Comments Assertion/Negation—Section 15.2.2, "Memory Address Attribute Signal Timing," refers to timing diagrams showing the relative timing of these signals and the rest of the memory interface.

2.2.5.10.2 PCI Address Attributes (PMAA[0:2])—Output

The memory attribute signals are associated with the PCI interface and provide information about the source of the PCI operation being performed by the MPC8240. They are also reset configuration input signals.

State Meaning Asserted/Negated—These signals are encoded to provide more detailed information about a PCI transaction. See Section 15.2.3, "PCI Address Attribute Signals," for a table showing these encodings.

Timing Comments Assertion/Negation—Section 15.2.4, "PCI Address Attribute Signal Timing," contains timing diagrams showing the relative timing of these signals and the rest of the PCI interface.

2.2.5.10.3 Debug Address (DA[0:15])—Output

When enabled, the debug address provides software disassemblers a simple way to reconstruct the 30-bit physical address for a memory bus transaction to DRAM and SDRAM, ROM, Flash, or PortX. Note that most of these signals are multiplexed with other signals (that may be inputs in their alternate function).

State Meaning Asserted/Negated—Section 15.3, "Memory Debug Address," describes these signals in detail, and how they are mapped to different address bits, depending on the type of memory in use.

Timing Comments Assertion/Negation— For DRAM or SDRAM, these 16 debug address signals are sampled with the column address and chip-selects. For ROM, Flash, and PortX devices, the debug address pins are sampled at the same time as the ROM address and can be used to recreate the 24-bit physical address in conjunction with ROM address.

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2.2.5.10.4 Memory Interface Valid ($\overline{\text{MIV}}$)—Output

The $\overline{\text{MIV}}$ signal is intended to help reduce the number of bus cycles that logic analyzers must store in memory during a debug trace by signalling when address and data signals should be sampled.

State Meaning Asserted—The memory interface valid signal, $\overline{\text{MIV}}$, is asserted whenever FPM, EDO, SDRAM, Flash, or ROM addresses or data are present on the external memory bus.

Timing Comments Assertion/Negation—Section 15.4.1, "MIV Signal Timing,"describes the relative timing of $\overline{\text{MIV}}$ in detail.

2.2.6 Test and Configuration Signals

The MPC8240 has several signals that are sampled during reset to determine the configuration of the ROM, Flash, and dynamic memory, and the phase-locked loop clock mode.

To facilitate system testing, the MPC8240 provides a JTAG test access port (TAP) that complies with the IEEE 1149.1 boundary-scan specification. This section also describes the JTAG test access port signals.

2.2.6.1 PLL Configuration (PLL_CFG[0:4])—Input

PLL_CFG[0:4] determine the clock frequency relationships of the PCI clock, the processor core frequency, and the *sys_logic_clk* signal (that determines the frequency of the memory interface clock). The multiplier factor determined by these signals on reset is stored in HID1[PLLRATIO]. However, system software cannot read the PLLRATIO value and associate it with a unique PLL_CFG[0:4] value. See Section 5.3.1.2.2, "Hardware Implementation-Dependent Register 1 (HID1)," for more information on HID1.

State Meaning Asserted—See the *MPC8240 Hardware Specification* for the supported settings.

Timing Comments Assertion—These signals are sampled at the negation of $\overline{\text{HRST\_CPU}}$ and $\overline{\text{HRST\_CTRL}}$ as part of the reset configuration signals. See Section 2.4, "Configuration Signals Sampled at Reset."

2.2.6.2 JTAG Test Clock (TCK)—Input

The JTAG test clock (TCK) signal is an input on the MPC8240. Following is the state meaning for the TCK input signal.

State Meaning Asserted/Negated—This input should be driven by a free-running clock signal with a 30–70% duty cycle. Input signals to the test access port are clocked in on the rising edge of TCK. Changes to the test access port output signals occur on the falling edge of TCK. The test logic allows TCK to be stopped.

Note that this input contains an internal pull-up resistor to ensure that an unterminated input appears as a high signal level to the test logic.

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2.2.6.3 JTAG Test Data Input (TDI)—Input

Following is the state meaning for the TDI input signal.

State Meaning Asserted/Negated—The value presented on this signal on the rising edge of TCK is clocked into the selected JTAG test instruction or data register.

Note that this input contains an internal pull-up resistor to ensure that an unterminated input appears as a high signal level to the test logic.

2.2.6.4 JTAG Test Data Output (TDO)—Output

Following is the state meaning for the TDO output signal.

State Meaning Asserted/Negated—The contents of the selected internal instruction or data register are shifted out onto this signal on the falling edge of TCK. The TDO signal remains in a high-impedance state except when scanning of data is in progress.

2.2.6.5 JTAG Test Mode Select (TMS)—Input

The test mode select (TMS) signal is an input on the MPC8240. Following is the state meaning for the TMS input signal.

State Meaning Asserted/Negated—This signal is decoded by the internal JTAG TAP controller to distinguish the primary operation of the test support circuitry.

Note that this input contains an internal pull-up resistor to ensure that an unterminated input appears as a high signal level to the test logic.

2.2.6.6 JTAG Test Reset ($\overline{\text{TRST}}$)—Input

The test reset ($\overline{\text{TRST}}$) signal is an input on the MPC8240. Following is the state meaning for the $\overline{\text{TRST}}$ input signal.

State Meaning Asserted—This input causes asynchronous initialization of the internal JTAG test access port controller. Note that the signal must be asserted during power-up reset in order to initialize properly the JTAG test access port.

Negated—Indicates normal operation.

Note that this input contains an internal pull-up resistor to ensure that an unterminated input appears as a high signal level to the test logic.

2.2.7 Clock Signals

The MPC8240 coordinates clocking across the memory bus and the PCI bus. This section provides a brief description of the MPC8240 clock signals. See Section 2.3, “Clocking,” for more detailed information on the use of the MPC8240 clock signals.

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2.2.7.1 System Clock Input (OSC_IN)—Input

Provides the input to the PCI clock fanout buffer. A clock can be connected to this input to provide multiple low-skew copies on the PCI_CLK[0:4] and PCI SYNC_OUT signals. For systems that do not use the fanout buffer feature, this signal should be tied to a fixed state.

2.2.7.2 PCI Clock (PCI_CLK[0:4])—Output

These signals provide multiple copies of OSC_IN as output signals when using the PCI clock fanout buffer feature. If these outputs are not needed, they can be individually disabled in the CDCR register to minimize power consumption.

2.2.7.3 PCI Clock Synchronize Out (PCI_SYNC_OUT)—Output

This output is an additional clock provided by the PCI clock fanout buffer. It is intended to be fed into the PCI_SYNC_IN signal to allow the internal clock subsystem to synchronize to the system PCI clocks.

2.2.7.4 PCI Feedback Clock (PCI_SYNC_IN)—Input

This signal provides the input to the peripheral logic PLL. The PLL multiplies up and synchronizes to this reference clock. The frequency of the PLL outputs is based on the PLL clock frequency configuration signal settings at reset. See the *MPC8240 Hardware Specification* for a complete listing of supported PLL_CFG[0:4] settings.

2.2.7.5 SDRAM Clock Outputs (SDRAM_CLK[0:3])—Output

The MPC8240 provides four low-skew copies of the SDRAM clock for use in small memory subsystems. This clock is synchronized to the on-chip logic using a DLL. If these outputs are not needed, they can be individually disabled in the CDCR register to minimize power consumption.

2.2.7.6 SDRAM Clock Synchronize Out (SDRAM_SYNC_OUT)—Output

SDRAM_SYNC_OUT is an advanced version of the SDRAM clock provided to allow feedback into the DLL to allow proper compensation for the output and flight time delay of the clock path.

2.2.7.7 SDRAM Feedback Clock (SDRAM_SYNC_IN)—Input

The SDRAM_SYNC_OUT signal should be connected to the SDRAM_SYNC_IN signal to allow the on -chip DLL to synchronize and compensate for routing delays and the output buffer.

For systems that use an external PLL to provide the clock source to SDRAM, this signal can be pulled high unless the SDRAM clock-to-PCI clock ratio is non-integer (3:2 or 5:2). In that case, this signal is used to synchronize between the internal clock and the external SDRAM clock.

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2.2.7.8 Debug Clock (CKO)—Output

The debug clock (CKO) signal is an output on the MPC8240. The internal signal reflected on CKO is determined by either the HID0[ECLK,SBCLK] bits (if PMCR1[CKO_SEL] = 0), or the two-bit PMCR1[CKO_MODE] field (if PMCR1[CKO_SEL] = 1).Both of these options allow the CKO output driver to be disabled. See Section 5.3.1.2.1, “Hardware Implementation-Dependent Register 0 (HID0),” and Section 4.3.1, “Power Management Configuration Register 1 (PMCR1)—Offset 0x70,” for more information.

Note that as described in Section 5.3.1.2.1, “Hardware Implementation-Dependent Register 0 (HID0)”, the processor core clock is driven on CKO while $\overline{\text{HRST\_CPU}}$ and $\overline{\text{HRST\_CTRL}}$ are asserted.

The signal on this output is derived from a variety of internal signals after passing through differing numbers of internal buffers. This signal is intended for use during system debug; it is not intended as a reference clock signal.

2.3 Clocking

The following sections describe the clocking on the MPC8240.

2.3.1 Clocking Method

The MPC8240 allows for multiple clock options to suit the needs of various system configurations. Internally, the MPC8240 uses a phase-locked loop (PLL) circuit to generate master clocks to the system logic and a second PLL to generate the processor clock. The system logic PLL is synchronized to the PCI_SYNC_IN input signal.

Figure 2-2 shows a block diagram of the clocking signals in the MPC8240.

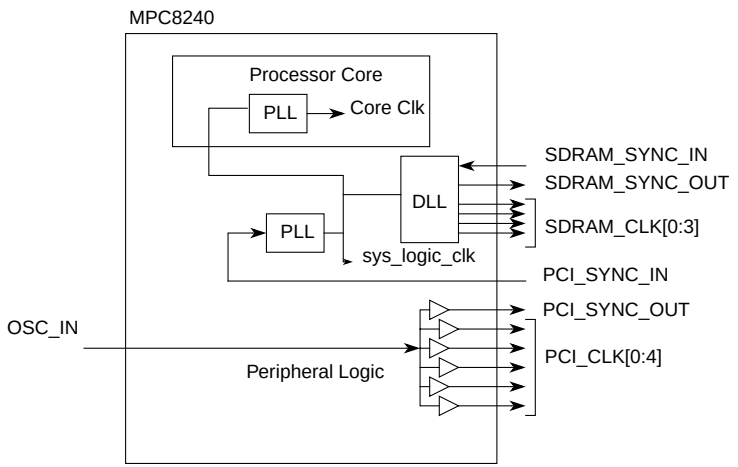

Figure 2-2. Clock Subsystem Block Diagram

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The *sys_logic_clk* signal may be set to a multiple of the PCI bus frequency as defined in the *MPC8240 Hardware Specification*. To help reduce the amount of discrete logic required in a system, the MPC8240 provides PCI clock fanout buffers. The MPC8240 also provides the memory clock (SDRAM_CLK*n*) signals through a delay locked loop (DLL) that is running at the same frequency as the internal system logic (*sys_logic_clk*).

Figure 2-3 shows the relationship of PCI_SYNC_IN and some multiplied clocks.

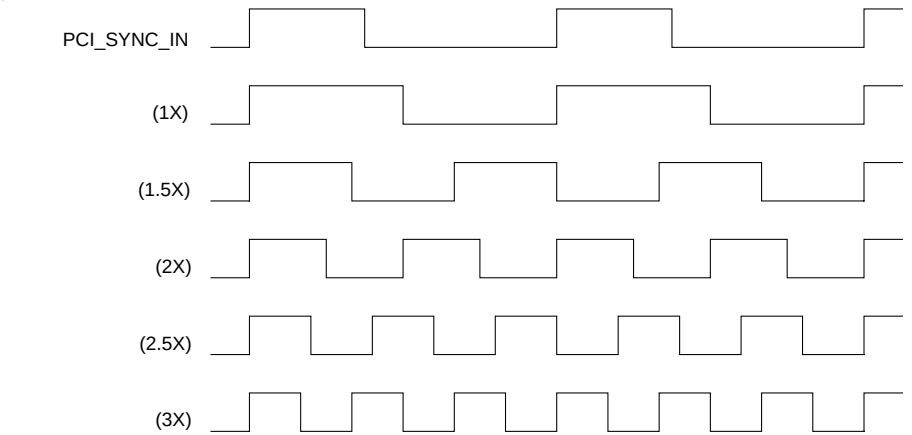

Figure 2-3. Timing Diagram (1X, 1.5X, 2X, 2.5X, and 3X examples)

NOTE:

PCI_SYNC_IN is not required to have a 50% duty cycle. Furthermore, the bus interface clocks, internal clock and PCI_SYNC_IN edges are phase-locked by the PLL.

The MPC8240 system logic PLL is configured by the PLL_CFG[0:4] signals at reset. For a given PCI frequency, these signals set the peripheral logic frequency and PLL (VCO) frequency of operation and determine the available multiplier frequencies for the processor core. The multiplier for the processor's PLL is further defined by PLL_CFG[0:4] and represented by the value in HID1[PLLRATIO]. See Section 5.3.1.2.2, "Hardware Implementation-Dependent Register 1 (HID1)," for more information on HID1. The supported settings for the PLL configuration pins are defined in the *MPC8240 Hardware Specifications*.

2.3.2 DLL Operation and Locking

The DLL on the MPC8240 generates the SDRAM_CLK[0:3] and SDRAM_SYNC_OUT signals. SDRAM_SYNC_OUT should be fed back through a delay loop into the SDRAM_SYNC_IN input of the MPC8240. By adjusting the length of the delay loop, it is possible to remove the effects of trace delay to the system memory. This is accomplished when the delay through the loop is equivalent to the delay to the system memory.

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The peripheral logic DLL is synchronized to SDRAM_SYNC_IN. Figure 2-2 shows how the PCI_SYNC_IN and SDRAM_SYNC_IN signals are independent of each other. These signals are supplied for synchronization of external components on the system board. For minimum skew between PCI_SYNC_OUT and the PCI_CLK*n* signals, the trace length on PCI_SYNC_IN should be designed so that it is the same as the trace lengths on the PCI_CLK*n* signals to their driven components. Similarly, for minimum skew, the loop length on SDRAM_SYNC_IN should be designed so that it is the same as the loop lengths on the SDRAM_CLK*n* signals to their driven components. For example, for minimum skew, if an SDRAM device has a 5-inch trace, the loop trace should be 5 inches in length. Note that a system designer may deliberately vary the loop lengths in order to introduce a distinct amount of skew between SDRAM_SYNC_OUT (PCI_SYNC_OUT) and the SDRAM_CLK*n (*PCI_CLK*n)* signals.

There are cases in which the DLL tap point may need to be explicitly altered. In this case, the DLL_EXTEND bit of PMCR2 can be written to shift the lock range of the DLL by half of an SDRAM clock cycle. Note that this bit should only be written during system initialization and should not be altered during normal operation. See *MPC8240 Hardware Specification* for more information about the use of DLL_EXTEND and the locking ranges supplied by the MPC8240.

There is a bit (DLL_RESET) in the AMBOR register that controls the initial tap point of the DLL. Note that although this bit is cleared after a hard reset, it must be explicitly set and then cleared by software during initialization in order to guarantee correct operation of the DLL and the SDRAM_CLK[0:3] signals (if they are used). Therefore, care must be taken when using SDRAM_CLK[0:3] to clock peripheral logic, as these clocks are not guaranteed to be operational until DLL_RESET is toggled in softtware as described above. See Section 4.9, “Address Map B Options Register—0xE0,” for more information about the DLL_RESET bit.

2.3.3 Clock Synchronization

The MPC8240 has the ability to provide the entire system with various system clocks based on PCI_SYNC_IN and the PLL_CFG[0:4] setting at reset. All of these clocks are synchronized by the internal logic of the MPC8240. In systems that use an external PLL to generate the memory system clocks and do not depend on the SDRAM_CLK[0:3] signals (shown in Figure 2-4), PCI_SYNC_IN must be phase-aligned with the input to the external PLL, and the MPC8240 system logic PLL should be programmed to have the same bus ratio as the external PLL in order to synchronize the internal processor bus and the internal peripheral logic to the memory interface.

In situations where the setting of PLL_CFG[0:4] creates a half-clock ratio between the PCI bus and processor bus, and an external PLL is being used to generate the memory system clocks, then SDRAM_SYNC_IN must be driven by the external PLL the same way as the SDRAM devices. In addition, clock flipping logic must be enabled through the reset configuration pin $\overline{\text{QACK}}$. This flipping ensures that the processor bus and internal logic will

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be synchronized to the external memory system clocks in half-clock modes. Also, by enabling the flipping during half-clock modes, the internal *hard_reset* to the processor core is delayed by 2^{17}(131072) processor clock cycles. This delay is required to insure that the clocking has been stabilized inside the MPC8240 after a reset.

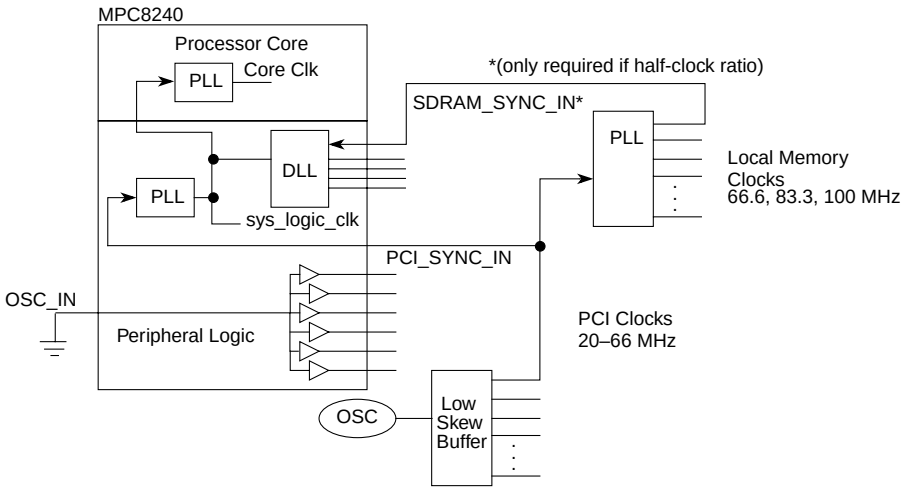

Figure 2-4. System Clocking with External PLL

2.3.4 Clocking System Solution Examples

This section describes two example clocking solutions for different system requirements. For systems where the MPC8240 is the host controller with a minimum number of clock loads, clock fanout buffers are provided on-chip (shown in Figure 2-5). For systems requiring more clock fanout or where the MPC8240 is an agent device, external clock buffers may be used as shown in Figure 2-6.

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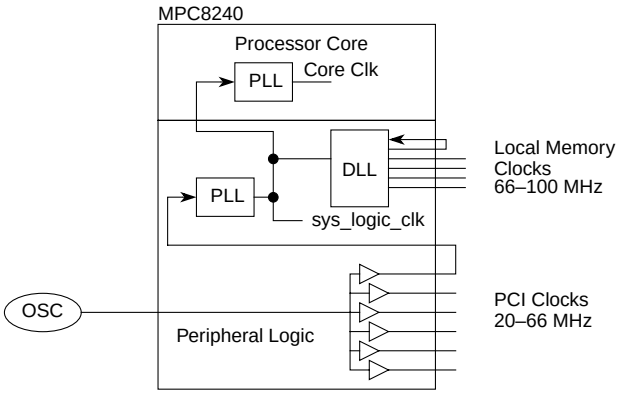

Figure 2-5. Clocking Solution—Small Load Requirements

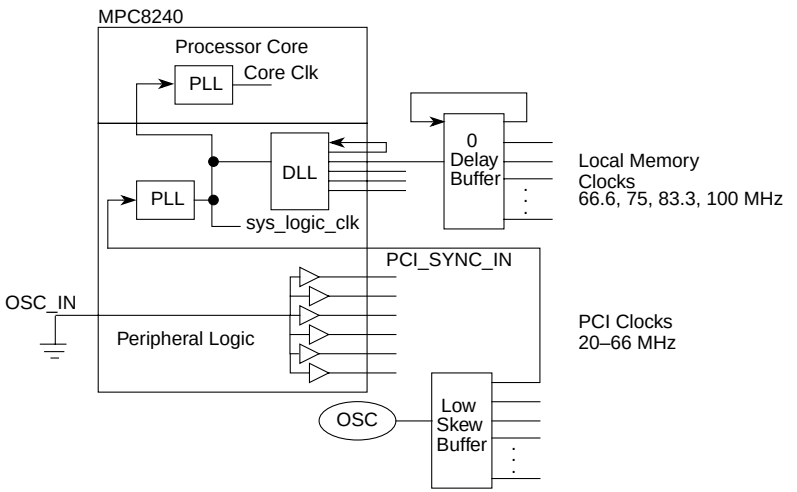

Figure 2-6. Clocking Solution—High Clock Fanout Required

2.4 Configuration Signals Sampled at Reset

Table 2-5 contains a description of the signals sampled for configuration at the negation of the $\overline{\text{HRST\_CTRL}}$ and $\overline{\text{HRST\_CPU}}$ signals. Note that throughout this manual, the reset configuration signals are described as being sampled at the negation of reset. However, the

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reset configuration signals are actually sampled 3 clock cycles before the negation of the HRST_CTRL and HRST_CPU signals, as described in the *MPC8240 Hardware Specification.* For more information about the timing requirements of these configuration signals relative to the negation of the reset signals, refer to the *MPC8240 Hardware Specification.*

The reset configuration signals serve multiple purposes, and the signal names do not reflect the functionality of the signals as they are used for reset configuration. The values on these signals during reset are interpreted to be logic one or zero, regardless of whether the signal name is defined as active-low. Most of the reset configuration signals have internal pull-up resistors so that if the signals are not driven, the default value is high (a one), as shown in the table. The PLL_CFG[0:4] signals do not have pull-up resistors and must be driven high or low during the reset period.

Table 2-5. MPC8240 Reset Configuration Signals

Signal Name(s)	Default	State Meaning
AS	1	Clock out select. Sets the initial value of PMCR1[CKO_SEL]: 0 Processor CKO; value on this signal determined by HID0[ECLK,SBCLK]. 1 Peripheral logic CKO; value on this signal determined by PMCR1[CKO_MODE] field.
MDL[0], FOE	11	Sets the initial ROM bank 0 data path width, DBUS_SIZE[0:1], values in MCCR1. DBUS_SIZE[0:1] = (MDL[0], FOE) at reset. For ROM/FLASH chip select #0 (RCS0), (MDL[0] = 0, FOE = 0) = 32-bit data bus. (MDL[0] = x, FOE = 1) = 8-bit data bus. (MDL[0] = 1, FOE = 0) = 64-bit data bus. For ROM/FLASH chip select #1 (RCS1) and memory data bus, (MDL[0] = 0, FOE = x) = 32-bit data bus. (MDL[0] = 1, FOE = x) = 64-bit data bus.
MAA0	1	Initial address map. The setting of this signal during reset sets the initial ADDRESS_MAP value in the PICR1 register. 0 The MPC8240 is configured for address map A (not supported when operating in PCI agent mode). 1 The MPC8240 is configured for address map B.
MAA1	1	MPC8240 host mode 0 MPC8240 is a PCI agent device 1 MPC8240 is a PCI master (host) device
MAA2	1	PCI arbiter disable—The value on this signal is inverted and then written as the initial value of bit 15 in the PCI arbiter control register (PACR). 0 PCI arbiter enabled 1 PCI arbiter disabled
MCP, CKE	11	PCI output hold delay value (in nanoseconds) relative to PCI_SYNC_IN. The values on these two signals determine the initial settings of PMCR2[6:5] as described in Section 4.3.2, “Power Management Configuration Register 2 (PMCR2)—Offset 0x72,” and the MPC8240 Hardware Specification. Note that the PMCR2 register has an additional bit (bit 4) that can be programmed to provide four more possible PCI output hold delay values. Refer to Section 4.3.2, “Power Management Configuration Register 2 (PMCR2)—Offset 0x72,” for more information on these settings

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Table 2-5. MPC8240 Reset Configuration Signals (Continued)

Signal Name(s)	Default	State Meaning
PMAA0	1	Driver capability for the MDH[0:31], MDL[0:31], PAR[0:7], MAA[0:2], and $\overline{\text{RCS1}}$ signals. Sets the initial value of the DRV_MEM _CTRL_1 bit in ODCR. Used in combination with PMAA1, as follows: 1 20-Ω data bus drive capability; when this is selected, only 8-Ω or 13.3-Ω drive capability allowed for PMAA1 0 40-Ω data bus drive capability; when this is selected, only 20-Ω or 40-Ω drive capability allowed for PMAA1
PMAA1	1	Driver capability for address signals ($\overline{\text{RAS}}$/$\overline{\text{CS}}$[0:7], $\overline{\text{CAS}}$/DQM[0:7], $\overline{\text{WE}}$, $\overline{\text{FOE}}$, $\overline{\text{RCS0}}$, SDBA0, $\overline{\text{SDRAS}}$, $\overline{\text{SDCAS}}$, CKE, $\overline{\text{AS}}$, and SDMA[12:0]). Sets the initial value of the DRV_MEM _CTRL_2 bit in the ODCR register.The meaning of this signal setting depends on the setting of PMAA0. The two signals and the meaning of their combined settings for the address signals are shown below: [PMAA0, PMAA1]: 11 8-Ω drive capability 10 13.3-Ω drive capability 01 20-Ω drive capability 00 40-Ω drive capability
PMAA2	1	Driver capability for PCI and EPIC controller output signals. The value of this signal sets the initial value of ODCR[DRV_PCI]. 0 High drive capability on PCI signals (25 Ω) 1 Medium drive capability on PCI signals (50 Ω)
$\overline{\text{QACK}}$	1	Clock flip disable. When this signal is low on reset, it enables internal clock flipping logic, which is necessary when the PLL[0:4] signals select a half-clock frequency ratio. See Section 2.3.3, “Clock Synchronization” for more information on the use of clock flipping. 0 Clock flip enabled 1 No clock flip
$\overline{\text{RCS0}}$	1	Boot memory location. The setting of this signal during reset sets the initial $\overline{\text{RCS0}}$ value in the PICR1 register 0 Indicates that boot ROM is located on the PCI bus. 1 Indicates that boot ROM is located on local processor/memory data bus.
PLL_CFG[0:4]	must be driven	These five signals select the clock frequency ratios used by the two PLLs of the MPC8240. The value of PLL_CFG[0:4] during reset affects the read-only PLLRATIO field stored in HID1. Note that system software cannot associate the PLLRATIO value with a unique PLL_CFG[0:4] value.The MPC8240 Hardware Specification lists the supported settings and provides more detailed information on the clock frequencies.
$\overline{\text{GNT4}}$	1	Debug address enable. See Section 15.3, “Memory Debug Address”, for more information about this function. 0 Debug address enabled; partial address of the transaction driven on DA[0:15]. 1 Debug address disabled

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Chapter 3
Address Maps

The MPC8240 in PCI host mode supports two address mapping configurations designated as address map A, and address map B. The address map is selected at reset by the MAA0 configuration pin. The address map selected at reset is stored as the initial value of the PICR1[ADDRESS_MAP] bit. If the MPC8240 is configured as a PCI host and the address map configuration pin is pulled low, the MPC8240 uses address map A. If the MPC8240 is configured as a PCI host and the address map configuration pin is pulled high, the MPC8240 uses address map B.

If the MPC8240 is configured as a PCI agent, it must be configured to use address map B. In agent mode, the MPC8240 offers address translation capability to allow address remapping for inbound and outbound PCI memory transactions. Translation allows a certain address space to map to a window of physical memory.

The MAA1 reset configuration pin selects whether the MPC8240 is operating as a PCI host or agent. For more information on the reset configuration signals, see Section 2.4, “Configuration Signals Sampled at Reset.”

Address map A conforms to the now-obsolete PowerPC reference platform (PReP) specification. It is strongly recommended that new designs use map B because map A may not be supported in future devices. For this reason, address map A is not described in this chapter; instead, it is described in Appendix A, “Address Map A.”

Address map B conforms to the PowerPC microprocessor common hardware reference platform (CHRP). When the MPC8240 is configured as a PCI agent, only map B is supported. This chapter describes map B.

The MPC8240 also has a block of local memory and PCI memory space that is allocated to the control and status registers for several embedded features. This block is called the embedded utilities memory block (EUMB). The EUMB and its offsets are also described in this chapter.

3.1 Address Map B

The address space of map B is divided into four areas—local memory, PCI memory, PCI I/O, and system ROM space. Throughout this chapter, the term local memory is used to mean that (S)DRAM is directly controlled by the MPC8240 memory controller.

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Table 3-1, Table 3-2, Table 3-3, and Table 3-4 show separate views of address map B for the processor core, a PCI memory device (host mode), a PCI memory device (agent mode), and a PCI I/O device, respectively. When configured for map B, the MPC8240 translates addresses across the internal peripheral logic bus and the external PCI bus as shown in Figure 3-1 through Figure 3-3.

Table 3-1. Address Map B—Processor View in Host Mode

Processor Core Address Range				PCI Address Range	Definition
Hex		Decimal			
0000_0000	3FFF_FFFF	0	1G - 1	No PCI cycle	Local memory space[1]
4000_0000	7FFF_FFFF	1G	2G - 1	No PCI cycle	Reserved
8000_0000	FDFF_FFFF	2G	4G - 32M - 1	8000_0000–FCFF_FFFF	PCI memory space[3]
FE00_0000	FE7F_FFFF	4G - 32M	4G - 32M + 64K - 1	0000_0000–0000_FFFF	PCI I/O space (8 Mbytes), 0-based[4]
FE80_0000	FEBF_FFFF	4G - 24M	4G - 20M - 1	0080_0000–00BF_FFFF	PCI I/O space (4 Mbytes), 0-based[5]
FEC0_0000	FEDF_FFFF	4G - 20M	4G - 18M - 1	CONFIG_ADDR	PCI configuration address register[6]
FEE0_0000	FEEF_FFFF	4G - 18M	4G - 17M - 1	CONFIG_DATA	PCI configuration data register[7]
FEF0_0000	FEFF_FFFF	4G - 17M	4G - 16M - 1	Interrupt acknowledge broadcast	PCI interrupt acknowledge
FF00_0000	FF7F_FFFF	4G - 16M	4G - 8M - 1	If ROM remote, then FF00_0000–FF7F_FFFF; if ROM local, then no PCI cycle	32- or 64-bit Flash/ROM space (8 Mbytes)[8]
FF80_0000	FFFF_FFFF	4G - 8M	4G - 1	If ROM remote, then FF80_0000–FFFF_FFFF; if ROM local, then no PCI cycle	8-, 32- or 64-bit Flash/ROM space (8 Mbytes)[9]

Table 3-2. Address Map B—PCI Memory Master View in Host Mode

PCI Memory Transaction Address Range				Local Memory Address Range	Definition
Hex		Decimal			
0000_0000	3FFF_FFFF	0	1G - 1	0000_0000–3FFF_FFFF	Local memory space[1]
4000_0000	7FFF_FFFF	1G	2G - 1	4000_0000–7FFF_FFFF	Reserved[2]
8000_0000	FDFF_FFFF	2G	4G - 32M - 1	No local memory cycle	PCI memory space[10, 11]
FE00_0000	FEFF_FFFF	4G - 32M	4G - 16M - 1	No local memory cycle	Reserved[11]
FF00_0000	FF7F_FFFF	4G - 16M	4G - 8M - 1	If ROM local, then FF00_0000–FF7F_FFFF; if ROM remote, then no local memory cycle	32- or 64-bit Flash/ROM space (8 Mbytes). Read-only area (writes cause Flash write error).[8]
FF80_0000	FFFF_FFFF	4G - 8M	4G - 1	If ROM local, then FF80_0000–FFFF_FFFF; if ROM remote, then no local memory cycle	8-, 32- or 64-bit Flash/ROM space (8 Mbytes). Read-only area (writes cause Flash write error).[9]

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Table 3-3. Address Map B—PCI Memory Master View in Agent Mode

PCI Memory Transaction Address Range	Processor Core Address Range	Definition
(PCSRBAR) – (PCSRBAR + 4 Kbytes)	—	PCI control and status registers
(LMBAR) – (LMBAR + window size)	—	Local memory space as defined by the address translation unit (ATU). See Section 3.3, “Address Translation,” for more information.

Table 3-4. Address Map B—PCI I/O Master View

PCI I/O Transaction Address Range				Processor Core Address Range	Definition
Hex		Decimal			
0000_0000	0000_FFFF	0	64K - 1	No system memory cycle	Addressable
0001_0000	007F_FFFF	64K	8M - 1	No system memory cycle	Not addressable
0080_0000	00BF_FFFF	8M	12M - 1	No system memory cycle	Addressable
00C0_0000	FFFF_FFFF	12M	4G - 1	No system memory cycle	Not addressable

Notes:

1. Part of address range is separately programmable (see Section 4.9, “Address Map B Options Register—0xE0”) for the processor interface and the PCI interface to control whether accesses to this address range go to local memory or PCI memory.
2. The MPC8240 generates a memory select error (if enabled; see Section 4.8.2, “Error Enabling and Detection Registers”) for transactions in the address range 4000_0000–7FFF_FFFF. If memory select errors are disabled, the MPC8240 returns all 1s for read operations and no update for write operations.
3. If AMBOR[CPU_FD_ALIAS_EN] = 1 (see Section 4.9, “Address Map B Options Register—0xE0”), the MPC8240 forwards processor transactions in part of this range to the zero-based PCI memory space with the 8 most significant bits cleared (that is, AD[31:0] = 0x00 || A[8:31] of the internal peripheral logic address bus).
4. Processor addresses are translated to PCI addresses as follows:
   PCI address (AD[31:0]) = 0x00 || A[8:31] to generate the address range 0000_0000–007F_FFFF. Note that only 64 Kbytes has been defined (0xFE00_0000–0xFE00–FFFF). The processor address range 0xFE01_0000–0xFE7F_FFFF is reserved for future use.
5. The MPC8240 forwards processor transactions in this range to the PCI I/O space with the 8 most significant bits cleared (that is, AD[31:0] = 0x00 || A[8:31]).
6. Each word in this address range is aliased to the PCI CONFIG_ADDR register. See Section 4.1, “Configuration Register Access.”
7. Each word in this address range is aliased to the PCI CONFIG_DATA register. See Section 4.1, “Configuration Register Access.”
8. The processor and PCI masters can access ROM/Flash on the local bus in the address range 0xFF00_0000–0xFF7F_FFFF if the ROM/Flash is configured to be on the local bus at reset, see Section 2.4, “Configuration Signals Sampled at Reset.” If PIRC2[CF_FF0_LOCAL] = 1, see Section 4.7, “Processor Interface Configuration Registers”; otherwise, the address is sent to PCI. This address range will always be treated as an access to a 32-, or 64-bit device as configured at reset if it is configured to be on the local bus.
9. The processor and PCI masters can access ROM/Flash on the local bus in the address range 0xFF70_0000–0xFFFF_FFFF if the ROM/Flash is configured to be on the local bus at reset (see Section 2.4, “Configuration Signals Sampled at Reset”); otherwise, the address is sent to PCI. This address range will be treated as an access to an 8-, 32-, or 64-bit device as configured at reset if it is configured to be on the local bus.
10. If AMBOR[PCI_FD_ALIAS_EN] = 1 (see Section 4.9, “Address Map B Options Register—0xE0”), the MPC8240 forwards PCI memory transactions in part of this range to local memory with the 8 most significant bits cleared (that is, 0x00 || AD[23:0]).
11. The MPC8240 will respond to PCI memory cycles in the range PCSRBAR to PCSRBAR + 4 Kbytes (for runtime registers). PCSRBAR can be programmed to be anywhere from 0x8000_0000 – 0xFCFF_FFFF or from 0xFE00_0000 – 0xFEFF_FFFF.

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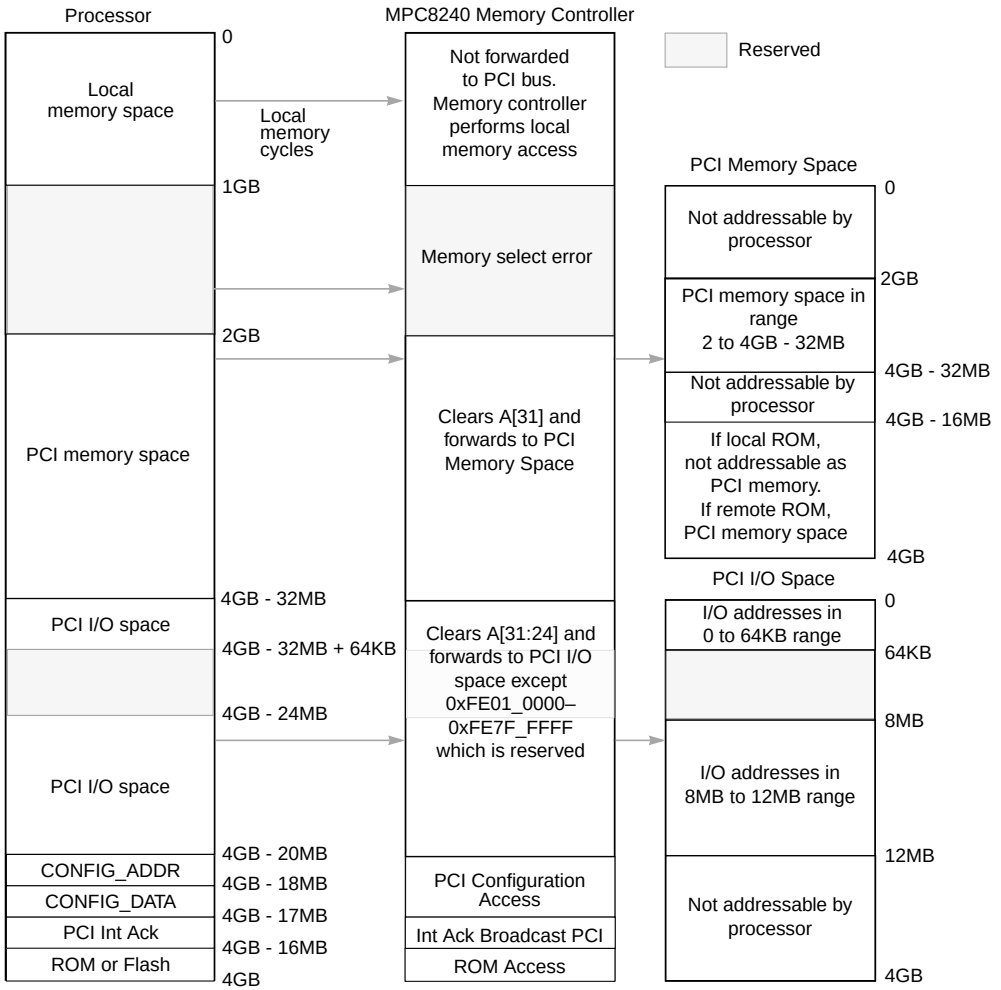

Figure 3-1. Processor Core Address Map B in Host Mode

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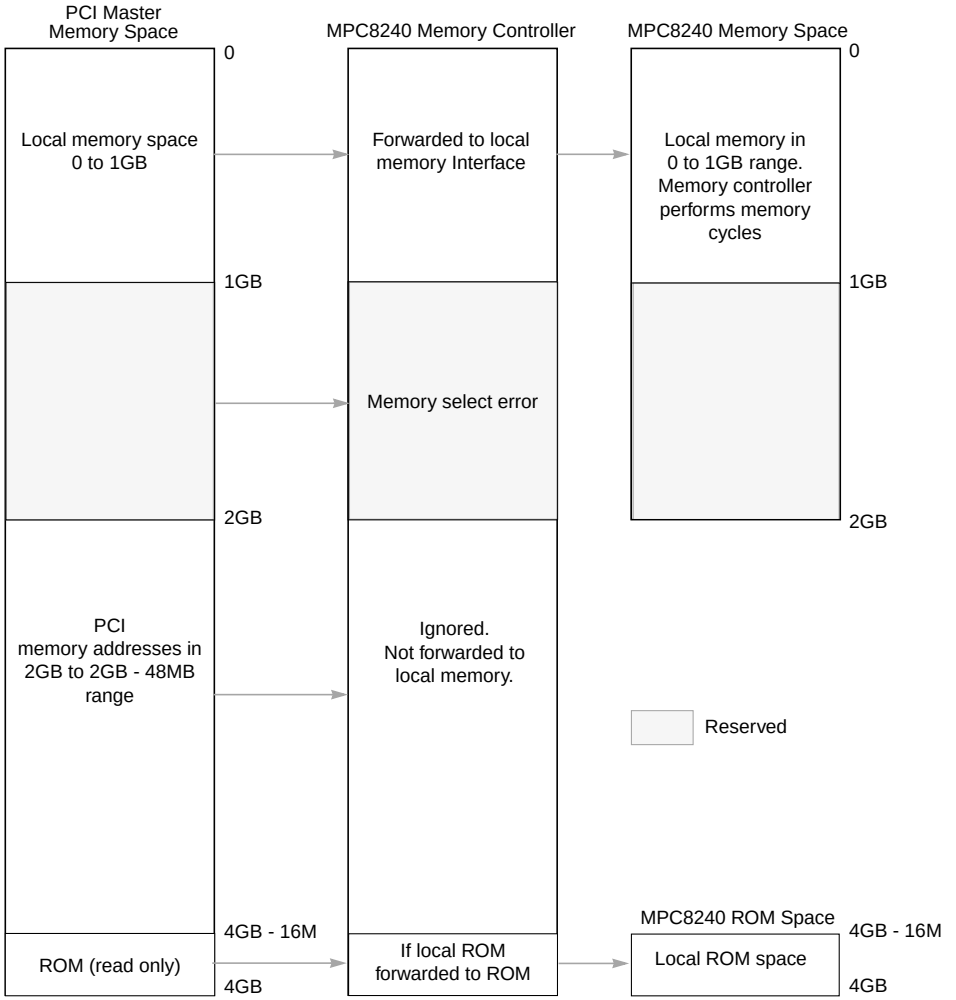

Figure 3-2. PCI Memory Master Address Map B in Host Mode

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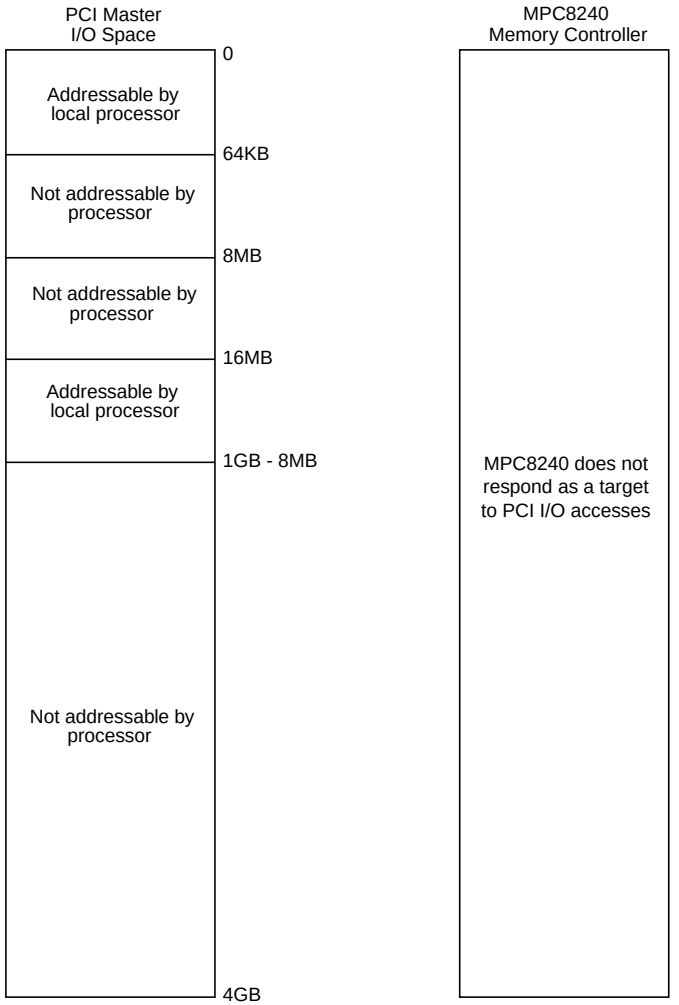

Figure 3-3. PCI I/O Master Address Map B

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3.2 Address Map B Options

When configured for address map B and host mode, the MPC8240 supports four optional address mappings by programming the AMBOR register; see Section 4.9, “Address Map B Options Register—0xE0.” The options available are as follows:

- Processor compatibility hole—This optional mapping creates a hole in the local memory space from 640 Kbytes to 768 Kbytes - 1. Processor core accesses to this range are forwarded untranslated to PCI memory space. The processor compatibility hole is provided for software compatibility with existing PC systems that may use the PCI memory space region from 640 Kbytes to 768 Kbytes - 1 for drivers, firmware, or buffers. The processor compatibility hole is enabled by setting the PROC_COMPATIBILITY_HOLE bit in the address map B options register (AMBOR).
- PCI compatibility hole—This optional mapping creates a hole in the local memory area of PCI memory space from 640 Kbytes to 1 Mbytes - 1. PCI accesses to this range are not claimed by the MPC8240. Thus, this range is available to PCI peripherals (such as video controllers) that require it. The PCI compatibility hole is provided for software compatibility with existing PC systems that may use the PCI memory space region from 640 Kbytes to 1 Mbyte - 1 for drivers, firmware, or buffers. The PCI compatibility hole is enabled by setting AMBOR[PCI_COMPATIBILITY_HOLE].
- Processor alias space—This optional mapping is used to translate processor accesses in the 16 Mbyte range starting at 0xFD00_0000 to the first 16 Mbytes of PCI memory space. The processor alias space is used to access devices that cannot be located above 16 Mbytes in PCI memory space (for example, ISA-compatible devices). The processor alias space is enabled by setting AMBOR[CPU_FD_ALIAS_EN].
- PCI alias space—This optional mapping is used to translate PCI memory space accesses in the 16 Mbyte range starting at 0xFD00_0000 to the first 16 Mbytes of local memory. Software may use the PCI alias space to access local memory in the 640 Kbyte to 1 Mbyte range when the PCI compatibility hole is enabled. The PCI alias space is enabled by setting AMBOR[PCI_FD_ALIAS_EN].

3.2.1 Processor Compatibility Hole and Alias Space

Table 3-5 defines the optional processor compatibility hole and processor alias space and how they fit into map B.

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Table 3-5. Address Map B—Processor View in Host Mode Options

Processor Core Address Range				PCI Address Range	Definition
Hex		Decimal			
0000_0000	0009_FFFF	0	640K - 1	No PCI cycle	Local memory space
000A_0000	000F_FFFF	640K	1M - 1	000A_0000–000F_FFFF	Compatibility hole[1]
0010_0000	3FFF_FFFF	1M	1G - 1	No PCI cycle	Local memory space
8000_0000	FCFF_FFFF	2G	4G - 48M - 1	8000_0000–FCFF_FFFF	PCI memory space
FD00_0000	FDFF_FFFF	4G - 48M	4G - 32M - 1	0000_0000–00FF_FFFF	PCI memory space (16 Mbytes), 0-based[2]
FE00_0000	FE7F_FFFF	4G - 32M	4G - 32M + 64K - 1	0000_0000–0000_FFFF	PCI I/O space (8 Mbytes), 0-based[3]

1. This address range is separately programmable (see Section 4.9, “Address Map B Options Register—0xE0”) for the processor interface and the PCI interface to control whether accesses to this address range go to local memory or PCI memory.
2. If AMBOR[CPU_FD_ALIAS_EN] = 1 (see Section 4.9, “Address Map B Options Register—0xE0”), the MPC8240 forwards processor transactions in this range to the zero-based PCI memory space with the 8 most significant bits cleared (that is, AD[31:0] = 0x00 || A[8:31] of the internal peripheral logic address bus).
3. Processor addresses are translated to PCI addresses as follows:
PCI address (AD[31:0]) = 0x00 || A[8:31] to generate the address range 0000_0000–007F_FFFF. Note that only 64 Kbytes has been defined (0xFE00_0000–0xFE00–FFFF). The processor address range 0xFE01_0000–0xFE7F_FFFF is reserved for future use.

Figure 3-4 shows the optional processor compatibility hole and processor alias space in map B.

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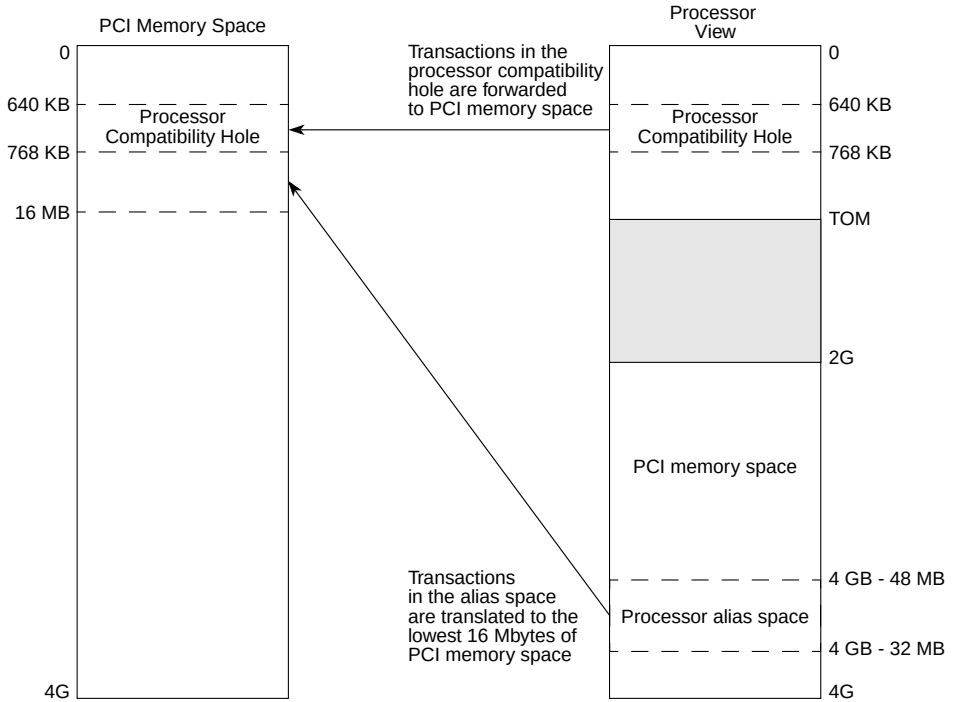

Figure 3-4. Address Map B Processor Options in Host Mode

3.2.2 PCI Compatibility Hole and Alias Space

Table 3-6 defines the optional PCI compatibility hole and PCI alias space and how they fit into map B.

Table 3-6. Address Map B—PCI Memory Master View in Host Mode Options

PCI Memory Transaction Address Range				Local Memory Address Range	Definition
Hex		Decimal			
0000_0000	0009_FFFF	0	640K- 1	0000_0000–0009_FFFF	Local memory space
000A_0000	000F_FFFF	640K	1M - 1	000A_0000–000F_FFFF	Compatibility hole[1]
0010_0000	3FFF_FFFF	1M	1G - 1	0010_0000–3FFF_FFFF	Local memory space
8000_0000	FDFF_FFFF	2G	4G - 48M - 1	No local memory cycle	PCI memory space[11]

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Table 3-6. Address Map B—PCI Memory Master View in Host Mode Options (Continued)

PCI Memory Transaction Address Range				Local Memory Address Range	Definition
Hex		Decimal			
FD00_0000	FDFF_FFFF	4G - 48M	4G - 32M - 1	0000_0000–00FF_FFFF	Local memory space (16 Mbytes), 0-based[2]
FE00_0000	FEFF_FFFF	4G - 32M	4G - 16M - 1	No local memory cycle	Reserved[3]

1. This address range is separately programmable (see Section 4.9, “Address Map B Options Register—0xE0”) for the processor interface and the PCI interface to control whether accesses to this address range go to local memory or PCI memory.
2. If AMBOR[PCI_FD_ALIAS_EN] = 1 (see Section 4.9, “Address Map B Options Register—0xE0”), the MPC8240 forwards PCI memory transactions in this range to local memory with the 8 most significant bits cleared (that is, 0x00 || AD[23:0]).
3. The MPC8240 will respond to PCI memory cycles in the range PCSRBAR to PCSRBAR + 4 Kbytes (for runtime registers). PCSRBAR can be programmed to be anywhere from 0x8000_0000 – 0xFCFF_FFFF or from 0xFE00_0000 – 0xFEFF_FFFF.

Figure 3-5 shows the optional PCI compatibility hole and PCI alias space in map B.

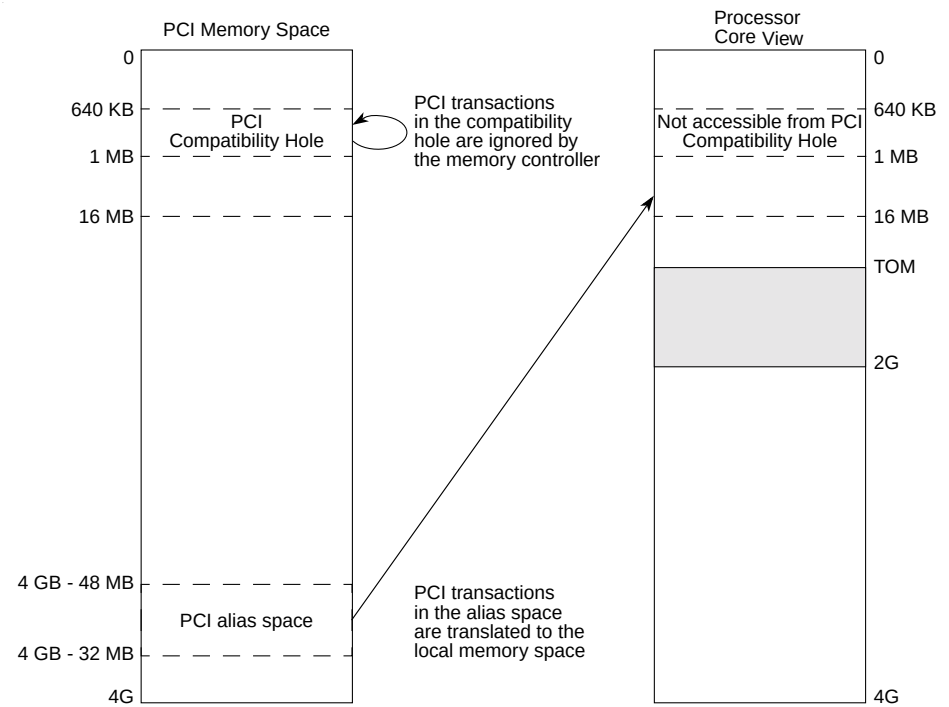

Figure 3-5. Address Map B PCI Options in Host Mode

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3.3 Address Translation

The MPC8240 allows remapping of PCI to local memory (inbound) transactions and processor core to PCI (outbound) transactions. Note that address translation is supported only for agent mode; it is not supported when the MPC8240 is operating in host mode. Also note that since agent mode is supported only for address map B, address translation is supported only for address map B. The following sections describe the address translation support of the MPC8240. Note that the address translation mechanisms are disabled upon reset.

All the configuration registers of the MPC8240 are intrinsically little-endian. In the register descriptions of this chapter, bit 0 is the least significant bit of the register. This bit numbering is based upon the PCI standard for register bit order numbering and is opposite from the standard PowerPC bit ordering where bit b0 is the most significant bit of the register.

3.3.1 Inbound PCI Address Translation

For inbound address translation, an inbound memory window is specified in PCI memory space and an inbound translation window is specified in the MPC8240's local memory space. PCI memory accesses in the inbound memory window are claimed by the MPC8240 and are forwarded to local memory with the address translated to the inbound translation window. PCI memory transactions outside of the inbound memory window are ignored (not claimed) by the MPC8240 unless they fall within the embedded utilities memory block (EUMB). PCI memory accesses that fall within the EUMB are handled as described in Section 3.4, "Embedded Utilities Memory Block (EUMB)," regardless of address translation.

Figure 3-6 shows inbound PCI address translation from PCI memory space to the local memory space.

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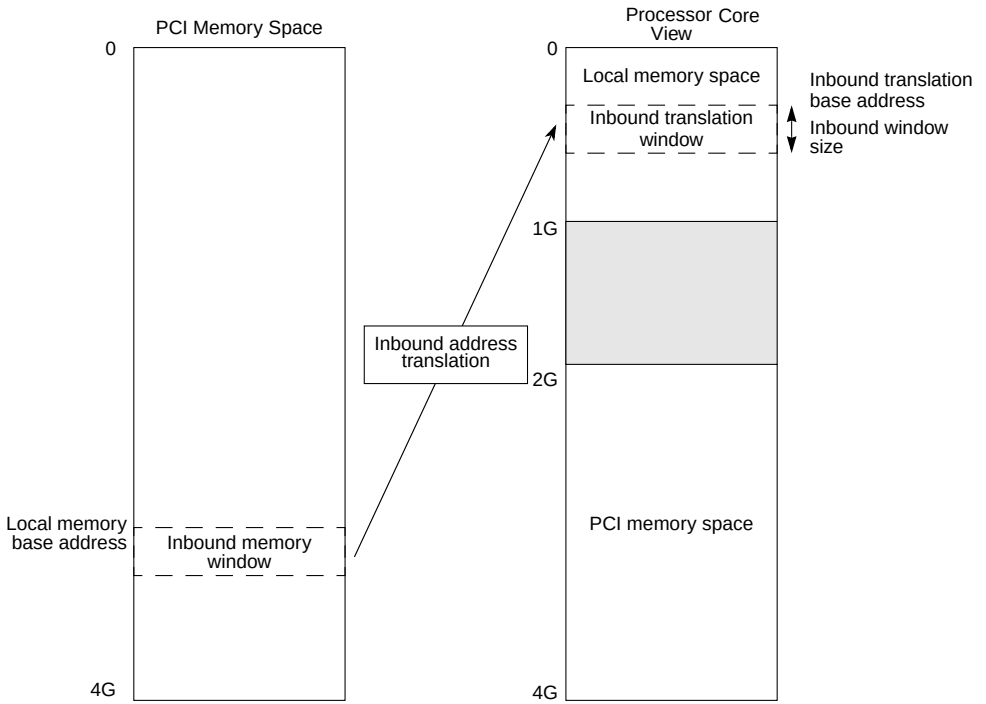

Figure 3-6. Inbound PCI Address Translation

Inbound address translation only allows address translation to the local memory space (the lower 1 Gbyte of the address space). This means that an external PCI master cannot access devices in the ROM/Port X address space when using inbound address translation. Since the local memory space is restricted to addresses below 0x4000_0000 (1 Gbyte), any access that gets translated above 0x4000_0000 triggers a memory select error. Thus, the entire inbound translation window must be programmed to be below 0x4000_0000.

The local memory base address register (LMBAR) and the inbound translation window register (ITWR) specify the location and size of the inbound memory window and the inbound translation window. These registers are described in Section 3.3.3, “Address Translation Registers.” Inbound address translation may be disabled by programming the inbound window size in the ITWR to all zeros. If inbound translation is disabled, the MPC8240 ignores all PCI memory transactions.

Note that overlapping the inbound memory window and the outbound translation window is not supported and can cause unpredictable behavior. Also note that the inbound memory window must not overlap the EUMB as specified by the PCSRBAR (PCI memory space view). See Section 3.4, “Embedded Utilities Memory Block (EUMB),” for more information.

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3.3.2 Outbound PCI Address Translation

For outbound translation, an outbound memory window is specified in the upper 2 Gbytes of the MPC8240's address space, and an outbound translation window is specified in the PCI memory space. Processor and DMA transactions that fall within the outbound memory window are forwarded to the PCI bus with the address translated to the outbound translation window. Outbound transaction addresses outside of the outbound memory window are forwarded to the PCI bus untranslated.

Figure 3-7 shows outbound PCI address translation from the processor core address space to PCI memory space.

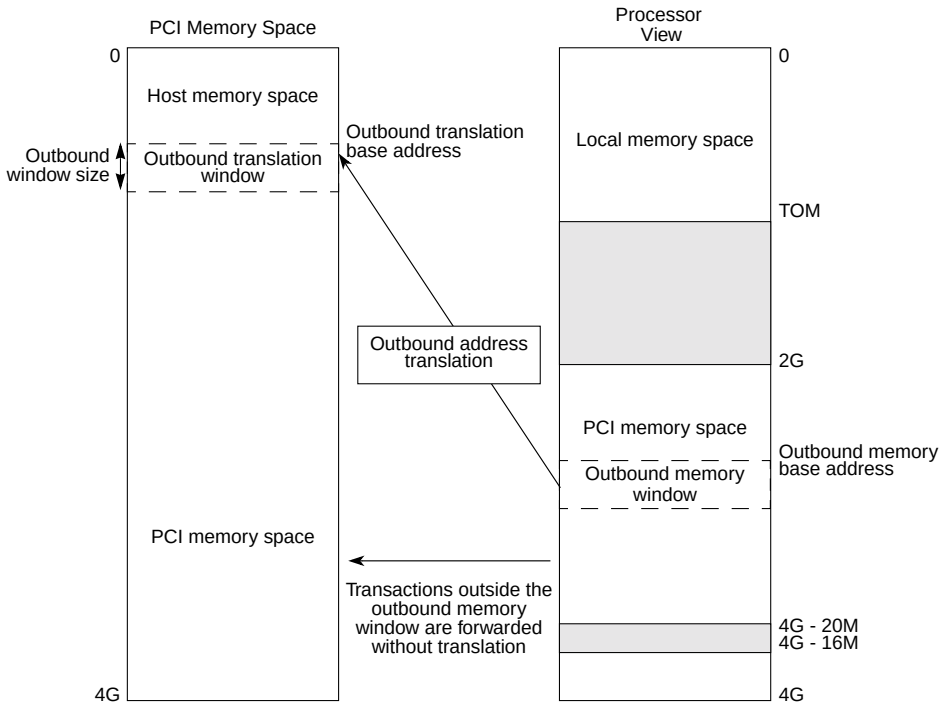

Figure 3-7. Outbound PCI Address Translation

Transactions to the MPC8240 address space marked as configuration address, configuration data, and interrupt acknowledge (0xFEC0_0000–0xFEFF_FFFF) are excluded from the outbound memory window. If the outbound memory base address is set to include this range, the MPC8240 will not translate the accesses to the outbound translation window. That is, the range appears as a hole in the outbound translation.

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The outbound memory base address register (OMBAR) and the outbound translation window register (OTWR) specify the location and size of the outbound memory window and the outbound translation window. These registers are described in Section 3.3.3, “Address Translation Registers.” Outbound address translation may be disabled by programming the outbound window size to all zeros.

Note that overlapping the inbound memory window and the outbound translation window is not supported and can cause unpredictable behavior. Also, the outbound memory window and the outbound translation window must not overlap with the EUMB as specified by the EUMBBAR (from the processor’s view) or the PCSRBAR (from the PCI memory space view). Operation is not guaranteed if the two are overlapping.

3.3.3 Address Translation Registers

This section describes the address translation registers in detail. The address translation registers, summarized in Table 3-7, specify the windows for inbound and outbound address translation.

Table 3-7. ATU Register Summary

Register Name	Location	Description
Local memory base address register (LMBAR)	MPC8240 internal configuration registers—see Chapter 4, “Configuration Registers” Offset 0x10	Specifies the starting address of the inbound memory window. PCI memory transactions in the inbound memory window are translated to the inbound translation window (specified in the ITWR) in local memory.
Inbound translation window register (ITWR)	EUMB—see Section 3.4, “Embedded Utilities Memory Block (EUMB)” Offset 0x0_2310 (local) Offset 0x310 (PCI)	Specifies the starting address of the inbound translation window and the size of the window.
Outbound memory base address register (OMBAR)	EUMB—see Section 3.4, “Embedded Utilities Memory Block (EUMB)” Offset 0x0_2300 (local) Offset 0x300 (PCI)	Specifies the starting address for the outbound memory window. Processor transactions in the outbound memory window are translated to the outbound translation window (specified in the OTWR) in PCI memory space.
Outbound translation window register (OTWR)	EUMB—see Section 3.4, “Embedded Utilities Memory Block (EUMB)” Offset 0x0_2308 (local) Offset 0x308 (PCI)	Specifies the starting address of the outbound translation window and the size of the window.

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3.3.3.1 Local Memory Base Address Register (LMBAR)

The LMBAR, shown in Figure 3-8 and Table 3-8, defines the inbound memory window.

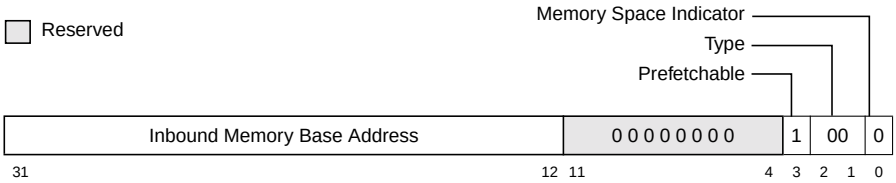

Figure 3-8. Local Memory Base Address Register (LMBAR)—0x10

Table 3-8. Bit Settings for LMBAR—0x10

Bits	Name	Reset Value	R/W	Description
31–12	Inbound memory base address	0x0000_0	R/W	Indicates the base address where the inbound memory window resides. The inbound memory window should be aligned based on the granularity specified by the inbound window size specified in the ITWR. Note that the EUMB area must be selected first, then the ITWR programmed, and then these bits can be set.
11–4	—	All 0s	R	Reserved; the MPC8240 only allows a minimum of a 4KByte window.
3	Prefetchable	1	R	Indicates that the space is prefetchable.
2–1	Type	00	R	The inbound memory window may be located anywhere within the 32-bit PCI address space.
0	Memory space indicator	0	R	Indicates PCI memory space.

3.3.3.2 Inbound Translation Window Register (ITWR)

The ITWR, shown in Figure 3-9 and Table 3-9, defines the inbound translation window and the inbound window size. The inbound window size in the ITWR sets the size of both the inbound translation window in local memory and the inbound memory window in PCI memory space. Software can alter the inbound translation base address in the ITWR during run-time to access different portions of local memory. Because the inbound memory base address in the LMBAR should be aligned to the inbound window size in the ITWR, the inbound window size should not be changed without also updating the LMBAR. As a general rule, the ITWR should be programmed before programming the LMBAR.

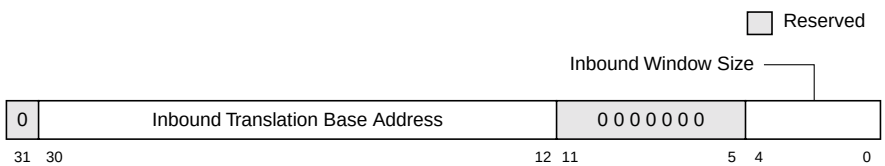

Figure 3-9. Inbound Translation Window Register (ITWR)

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Table 3-9. Bit Settings for ITWR—0x0_2310

Bits	Name	Reset Value	R/W	Description
31	—	0	R	Reserved. Translated addresses can only be targeted at local memory in the lower 2 Gbytes of the MPC8240 address space.
30–12	Inbound translation base address	Undefined	R/W	Local memory address that is the starting address for the inbound translation window. The inbound translation window should be aligned based on the granularity specified by the inbound window size.
11–5	—	All 0s	R	Reserved
4–0	Inbound window size	All 0s	R/W	Inbound window size. The inbound window size is encoded as N where the window size is 2^{N+1} bytes. The minimum window size is 4 Kbytes; the maximum window size is 1 Gbyte. Note that the inbound window size sets the size of both the inbound memory window and the inbound translation window. 00000 Inbound address translation disabled 00001 Reserved ... 01010 Reserved 01011 2^{12} = 4 Kbyte window size 01100 2^{13} = 8 Kbyte window size 01101 2^{14} = 16 Kbyte window size ... 11101 2^{30} = 1 Gbyte window size 11110 Reserved 11111 Reserved Note that the inbound memory window must not overlap with the EUMB.

The lower-order address bits of the base address field of ITWR that are within the range specified by the window size are ignored and the MPC8240 ignores the incoming lower-order address bits (within the range specified by the window size). However, for future compatibility, it is recommended that the base address be programmed to be naturally aligned to the window size. For example, if the window size is programmed as 1 Mbyte, then the base address should be aligned to a 1-Mbyte boundary (as ITWR[19–12] are not used to determine if there is a hit to the inbound translation window for a 1-Mbyte window).

3.3.3.3 Outbound Memory Base Address Register (OMBAR)

The OMBAR, shown in Figure 3-10 and Table 3-10, defines the outbound memory window.

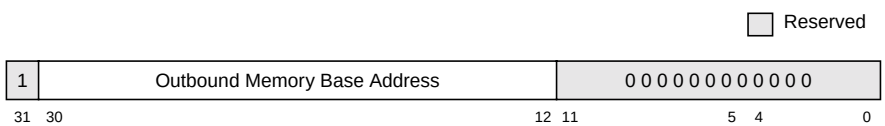

Figure 3-10. Outbound Memory Base Address Register (OMBAR)—0x0_2300

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Table 3-10. Bit Settings for OMBAR—0x0_2300

Bits	Name	Reset Value	R/W	Description
31	—	1	R	Reserved. The outbound memory window must reside in the upper 2 Gbytes of the MPC8240 address space.
30–12	Outbound memory base address	Undefined	R/W	Processor address that is the starting address for the outbound memory window. The outbound memory window must be aligned based on the granularity specified by the outbound window size specified in the OTWR.
11 – 0	—	All 0s	R	Reserved

3.3.3.4 Outbound Translation Window Register (OTWR)

The OTWR, shown in Figure 3-11 and Table 3-11, defines the outbound translation window and outbound window size. The outbound window size in the OTWR sets the size of both the outbound translation window in PCI memory space and the outbound memory window in the processor address space. Software can alter the outbound translation base address and the outbound translation window size during runtime. This allows software to scroll through host memory or address alternate space as needed.

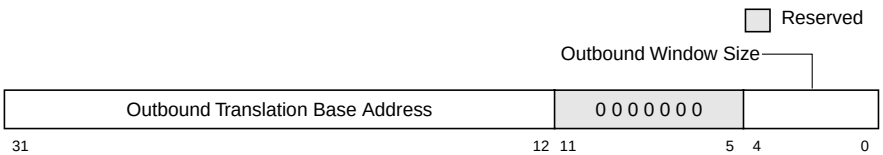

Figure 3-11. Outbound Translation Window Register (OTWR)—0x0_2308

Table 3-11. Bit Settings for OTWR—0x0_2308

Bits	Name	Reset Value	R/W	Description
31–12	Outbound translation base address	Undefined	R/W	PCI memory address—the starting address for the outbound translation window. The outbound translation window should be aligned based on the granularity specified by the outbound window size.
11–5	—	All 0s	R	Reserved
4–0	Outbound window size	All 0s	R/W	Outbound window size—The outbound window size is encoded as N where the window size is 2^{N+1} bytes. The minimum window size is 4 Kbytes; the maximum window size is 1 Gbyte. Note that the outbound window size sets the size of both the outbound memory window and the outbound translation window. 00000 Outbound address translation disabled 00001 Reserved ... 01010 Reserved 01011 2^{12} = 4 Kbyte window size 01100 2^{13} = 8 Kbyte window size 01101 2^{14} = 16 Kbyte window size ... 11101 2^{30} = 1 Gbyte window size 11110 Reserved 11111 Reserved Note that the outbound memory window must not overlap with the EUMB.

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The lower-order address bits of the base address field of OTWR that are within the range specified by the window size are ignored and the MPC8240 ignores the outgoing lower-order address bits (within the range specified by the window size). However, for future compatibility, it is recommended that the base address be programmed to be naturally aligned to the window size.

3.4 Embedded Utilities Memory Block (EUMB)

The MPC8240 contains several embedded features that require control and status registers. These registers are accessible during normal operation. The features include the DMA controller, message unit, EPIC, I^2C, ATU, and memory data path diagnostic logic (including watchpoint facility). These registers in some cases are accessible by both the processor core and the PCI bus. The collection of these units is called the embedded utilities. These registers comprise the runtime registers and a block of local memory and PCI memory space is allocated to them.

The embedded utilities memory block (EUMB) is relocatable both in PCI memory space (for PCI access) and local memory space (for processor access). The local memory map location of this register block is controlled by the embedded utilities memory block base address register (EUMBBAR). In the processor's local memory map, the registers that comprise the EUMB (specified by the EUMBBAR) are restricted to locations 0x8000_0000 to 0xFDFF_FFFF; see Section 3.4, "Embedded Utilities Memory Block (EUMB)." The PCI bus memory map location for this block is controlled by the peripheral control and status registers base address register (PCSRBAR). In the PCI memory space, the registers of the EUMB (specified by PCSRBAR) may reside in any unused portion of the PCI memory space; see Section 4.2.7, "PCI Base Address Registers—LMBAR and PCSRBAR."

Note that the EUMB should not reside inside either the outbound memory window or the outbound translation window. Operation is not guaranteed if the two are overlapping. Note that the processor must not run transactions to the PCI memory space allocated for the EUMB by the PCSRBAR.

All registers in the EUMB are accessible with 32-bit accesses only. Transactions of sizes other than 32-bit are considered a programming error, and operation is not guaranteed if they are used. Additionally, accesses to the EUMB must be strictly ordered. Therefore, the EUMB should be marked caching-inhibited and guarded using the WIMG memory/cache access attributes in the processor's BAT or page table entries. Note that the **eieio** instruction has no effect on the MPC603e and MPC750 families of processors.

3.4.1 Processor Core Control and Status Registers

The location of the memory mapped registers of the EUMB that are accessible by the processor for the message unit, DMA controller, ATU, I^2C controller, EPIC unit, and memory data path diagnostic logic are shown in Figure 3-12.

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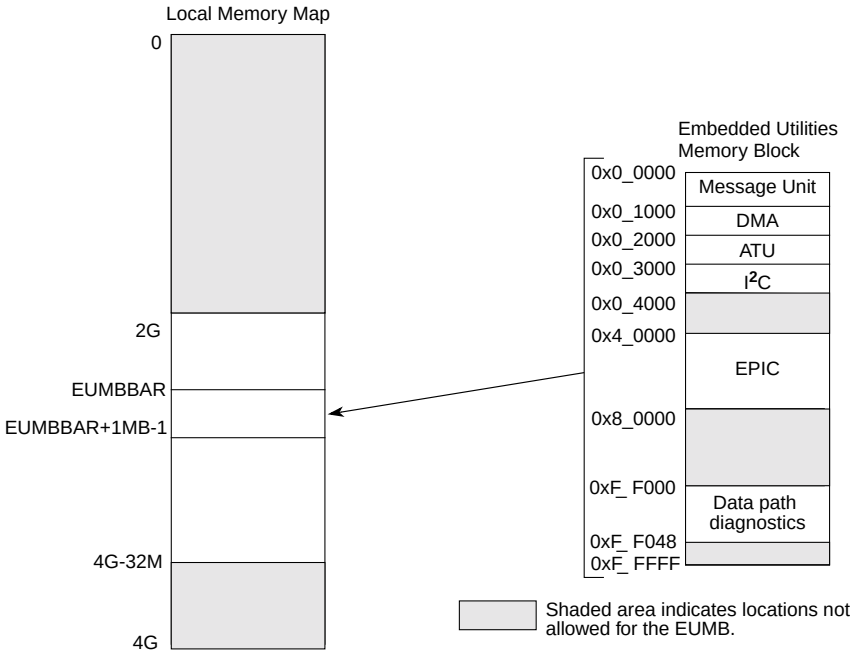

Figure 3-12. Embedded Utilities Memory Block Mapping to Local Memory

Table 3-12 summarizes the embedded utilities local memory registers and their offsets.

Table 3-12. Embedded Utilities Local Memory Register Summary

Local Memory Offset	Register Set	Reference
0x0_0000 - 0x0_0FFF	Message registers, Doorbell interface, I_2O	Section 9.2.1, “Message and Doorbell Register Summary” and Section 9.3.2, “I2O Register Summary”
0x0_1000 – 0x0_1FFF	DMA controller	Section 8.2, “DMA Register Summary”
0x0_2000 – 0x0_2FFF	ATU	Section 3.3.3, “Address Translation Registers”
0x0_3000 – 0x0_3FFF	I^2C controller	Section 10.3, “I2C Register Descriptions”
0x0_4000 – 0x3_FFFF	Reserved	—
0x4_0000 – 0x7_FFFF	EPIC controller	Section 11.2, “EPIC Register Summary”
0x8_0000 – 0xF_EFFF	Reserved	—
0xF_F000 – 0xF_F017	Data path diagnostics	Section 15.1, “Debug Register Summary”
0xF_F018 – 0xF_F048	Data path diagnostics (watchpoint registers)	Chapter 16, “Programmable I/O and Watchpoint”
0xF_F04D – 0xF_FFFF	Reserved	—

3.4.2 Peripheral Control and Status Registers

The MPC8240 contains a set of memory mapped registers that are accessible from the PCI bus in both host and agent mode. These registers allow external masters on the PCI bus to access the MPC8240’s on-chip embedded utilities such as the message unit, DMA

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controller, ATU, and memory data path diagnostic logic as shown in Figure 3-13. The region requires 4 Kbytes of PCI memory space. The base address for this region is selectable through the PCI configuration register PCSRBAR (see Section 4.2.7, “PCI Base Address Registers—LMBAR and PCSRBAR”).

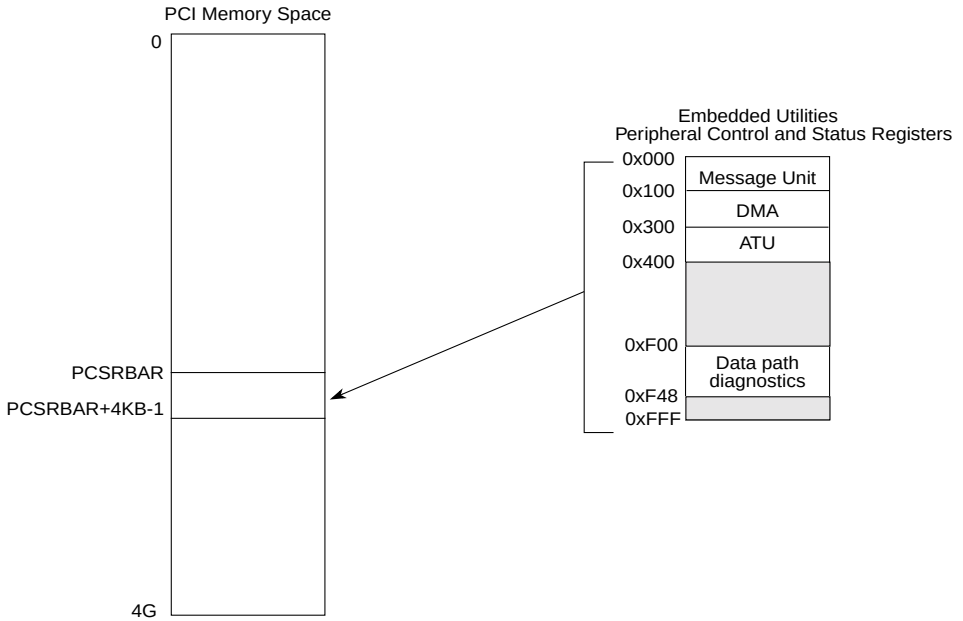

Figure 3-13. Embedded Utilities Memory Block Mapping to PCI Memory

Table 3-13 summarizes the embedded utilities registers accessible by the PCI bus and their offsets.

Table 3-13. Embedded Utilities Peripheral Control and Status Register Summary

PCI Memory Offset	Register Set	Reference
0x000 – 0x0FF	Message registers, doorbell interface, I_2O	Section 9.2.1, “Message and Doorbell Register Summary” and Section 9.3.2, “I2O Register Summary”
0x100 – 0x2FF	DMA controller	Section 8.2, “DMA Register Summary”
0x300 – 0x3FF	ATU	Section 3.3.3, “Address Translation Registers”
0x400 – 0xEFF	Reserved	—
0xF00 – 0xF17	Data path diagnostics	Section 15.1, “Debug Register Summary
0xF18 – 0xF48	Data path diagnostics (watchpoint registers)	Chapter 16, “Programmable I/O and Watchpoint
0xF4D – 0xFFF	Reserved	—

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Chapter 4
Configuration Registers

This chapter describes the programmable configuration registers of the MPC8240. These registers are generally set up by initialization software following a power-on reset, hard reset, or error handling routines. All the configuration registers of the MPC8240 are intrinsically little-endian. In the register descriptions of this chapter, bit 0 is the least significant bit of the register. This bit numbering is based upon the PCI standard for register bit order numbering and is opposite from the standard PowerPC bit ordering where bit b0 is the most significant bit of the register.

Reserved bits in the register descriptions are not guaranteed to have predictable values. Software must preserve the values of reserved bits when writing to a configuration register. Also, when reading from a configuration register, software should not rely on the value of any reserved bit remaining consistent. Thus, the values of reserved bit positions must first be read, merged with the new values for other bit positions, and then written back. Software should use the transfer size shown in the register bit descriptions throughout this chapter.

4.1 Configuration Register Access

The MPC8240 configuration registers are accessible from the processor core through memory-mapped configuration ports. The registers are accessed by an indirect method similar to accessing PCI device configuration registers. A 32-bit register address 0x8000_00nn, where nn is the address offset of the desired configuration register (see Table 4-2 and Figure 4-1), is written to the CONFIG_ADDR port. Then, the data is accessed at the CONFIG_DAT port. The locations of these ports are described in Table 4-1.

Table 4-1. Internal Register Access Port Locations

Address Map	CONFIG_ADDR	CONFIG_DAT
A (see Appendix A, “Address Map A”)	0x8000_0CF8	0x8000_0CFC–0x8000_0CFF
B	Any word-aligned address within the range 0xFEC0_0000–0xFEDF_FFFC*	0xFEE0_0000–0xFEEF_FFFF[1]

[1] Every word within this range is aliased to the same location

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A subset of the configuration registers is accessible from the PCI bus through the use of PCI configuration transactions. The MPC8240 responds to standard PCI configuration transactions when its IDSEL signal is asserted. Table 4-3 provides a listing of configuration registers accessible from the PCI bus.

Note that the address loaded into CONFIG_ADDR is used as a word address and does not have byte granularity. Therefore, care must be taken when accessing configuration registers that have a 1-or 2-byte size when the address of that register is not word-aligned. In this case the **stb** or **sth** instructions must use an <ea> with the appropriate offset for that byte or word, as shown in the following examples.

4.1.1 Configuration Register Access in Little-Endian Mode

When the processor and peripheral logic are in little-endian mode, the program should access the configuration registers using the method described in Section 4.1, "Configuration Register Access." This section provides several examples of configuration register access in little-endian mode.

The configuration register address (CONFIG_ADDR) in the processor register should appear (as data appears) in descending byte order (MSB to LSB) when it is stored to the peripheral logic. The configuration data (CONFIG_DATA) appears in the processor register in descending significance byte order (MSB to LSB) at the time it is loaded or stored to the peripheral logic.

Example: Map B address map configuration sequence, 4-byte data write to register at address offset 0xA8

```
Initial values: r0 contains 0x8000_00A8
        r1 contains 0xFEC0_0000
        r2 contains 0xFEE0_0000
        r3 contains 0xAABB_CCDD
        Register at 0xA8 contains 0xFFFF_FFFF (AB to A8)

Code sequence:  stw     r0,0(r1)
                sync
                stw     r3,0(r2)
                sync

Results:Address 0xFEC0_0000 contains 0x8000_00A8 (MSB to LSB)
        Register at 0xA8 contains 0xAABB_CCDD (AB to A8)
```

Example: Map B address map configuration sequence, 1-byte data write to register at address offset 0xAA

```
Initial values: r0 contains 0x8000_00A8
        r1 contains 0xFEC0_0000
        r2 contains 0xFEE0_0000
        r3 contains 0xAABB_CCDD
        Register at 0xA8 contains 0xFFFF_FFFF (AB to A8)
```

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```
Code sequence:  stw     r0,0(r1)
                sync
                stb     r3,2(r2)
                sync

Results:Address 0xFEC0_0000 contains 0x8000_00A8 (MSB to LSB)
        Register at 0xA8 contains 0xFFDD_FFFF (AB to A8)
```

Example: Map A configuration sequence, 4-byte data write to register at address offset 0xA8

```
Initial values:r0 contains 0x8000_00A8
        r1 contains 0x8000_0CF8
        r2 contains 0xAABB_CCDD
        Register at 0xA8 contains 0xFFFF_FFFF (AB to A8)

Code sequence:  stw     r0,0(r1)
                sync
                stw     r2,4(r1)
                sync

Results:Address 0x8000_0CF8 contains 0x8000_00A8 (MSB to LSB)
        Register at 0xA8 contains 0xAABB_CCDD (AB to A8)
```

Example: Map A configuration sequence, 2-byte data write to register at address offset 0xAA. (Note that in this example, the value 0x8000_00A8 is the configuration address register, not 0x8000_00AA. The address offset 0xAA is generated by using 0x8000_0CFE for the data access.)

```
Initial values:r0 contains 0x8000_00A8
        r1 contains 0x8000_0CF8
        r2 contains 0xAABB_CCDD
        Register at 0xA8 contains 0xFFFF_FFFF (AB to A8)

Code sequence:  stw     r0,0(r1)
                sync
                sth     r2,6(r1)
                sync

Results:Address 0x8000_0CF8 contains 0x8000_00A8 (MSB to LSB)
        Register at 0xA8 contains 0xCCDD_FFFF (AB to A8)
```

Example: Map A configuration sequence, 1-byte data read from register at address offset 0xA9

```
Initial values:r0 contains 0x8000_00A8
        r1 contains 0x8000_0CF8
        Register at 0xA8 contains 0xAABB_CCDD (AB to A8)
Code sequence:  stw     r0,0(r1)
                sync
                lbz     r2,5(r1)
                sync
Results:Address 0x8000_0CF8 contains 0x8000_00A8 (MSB to LSB)
        r2 contains 0x0000_00CC
```

4.1.2 Configuration Register Access in Big-Endian Mode

When the processor and peripheral logic are in big-endian mode, software must either use the load/store with byte reversed instructions (**lhbrx**, **lwbrx**, **sthbrx**, and **stwbrx**) or

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byte-swap the CONFIG_ADDR and CONFIG_DATA values before performing an access (that is, software loads the configuration register address and the configuration register data into the processor register in ascending byte order—LSB to MSB).

Note that in the following examples, the data in the configuration register (at 0xA8) is shown in little-endian order. This is because all the internal registers are intrinsically little-endian.

Example: Map B address map configuration sequence, 4-byte data write to register at address offset 0xAA using store word with byte reversed instructions

```
Initial values:r0 contains 0x8000_00A8
        r1 contains 0xFEC0_0000
        r2 contains 0xFEE0_0000
        r3 contains 0xAABB_CCDD
        Register at 0xA8 contains 0xFFFF_FFFF (AB to A8)

Code sequence:  stwbrx  r0,0,r1
                sync
                stwbrx  r3,0,r2
                sync

Results:Address 0xFEC0_0000 contains 0x8000_00A8 (MSB to LSB)
Register at 0xA8 contains 0xAABB_CCDD (AB to A8)
```

Example: Map B address map configuration sequence, 2-byte data write to register at address offset 0xAA, using byte-swapped values in the processor registers

```
Initial values:r0 contains 0xA800_0080
        r1 contains 0xFEC0_0000
        r2 contains 0xFEE0_0000
        r3 contains 0xDDCC_BBAA
        Register at 0xA8 contains 0xFFFF_FFFF (AB to A8)

Code sequence:  stw     r0,0(r1)
                sync
                sth     r3,2(r2)
                sync

Results:Address 0xFEC0_0000 contains 0x8000_00A8 (MSB to LSB)
Register at 0xA8 contains 0xAABB_FFFF (AB to A8)
```

Example: Map A configuration sequence, 2-byte data write to register at address offset 0xA8, using store with byte-reversed instructions

```
Initial values:r0 contains 0x8000_00A8
        r1 contains 0x8000_0CF8
        r2 contains 0xAABB_CCDD
        r3 contains 0x8000_0CFC
        Register at 0xA8 contains 0xFFFF_FFFF (AB to A8)

Code sequence:  stwbrx  r0,0,r1
                sync
                sthbrx  r2,0,r3
                sync

Results:Address 0x8000_0CF8 contains 0x8000_0004 (MSB to LSB)
Register at 0xA8 contains 0xFFFF_CCDD (AB to A8)
```

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Example: Map A configuration sequence, 4-byte data write to register at address offset 0xA8, using byte-swapped values in the processor registers

```
Initial values:r0 contains 0xA800_0080
       r1 contains 0x8000_0CF8
       r2 contains 0xDDCC_BBAA
       Register at 0xA8 contains 0xFFFF_FFFF (AB to A8)

Code sequence:  stw     r0,0(r1)
                sync
                stw     r2,4(r1)
                sync

Results:Address 0x8000_0CF8 contains 0x8000_00A8 (MSB to LSB)
Register at 0xA8 contains 0xAABB_CCDD (AB to A8)
```

4.1.3 Configuration Register Summary

The following sections summarize the addresses and attributes of the configuration registers accessible by both the processor and the PCI interface.

4.1.3.1 Processor-Accessible Configuration Registers

Table 4-2 describes the configuration registers that are accessible by the processor core. Not all registers are shown in this document. Note that any configuration addresses not defined in Table 4-2 are reserved.

Table 4-2. MPC8240 Configuration Registers Accessible from the Processor Core

Address Offset	Register	Size	Program Access Size (Bytes)	Access	Reset Value
0x00	Vendor ID = 0x1057 (not shown)	2 bytes	2	Read	0x1057
0x02	Device ID = 0x0003 (not shown)	2 bytes	2	Read	0x0003
0x04	PCI command register	2 bytes	2	Read/Write	mode-dependent 0x0004 host 0x0000 agent
0x06	PCI status register	2 bytes	2	Read/Bit Reset	0x00A0
0x08	Revision ID (not shown)	1 byte	1	Read	0xnn
0x09	Standard programming interface	1 byte	1	Read	mode-dependent 0x00 host 0x01 agent
0x0A	Subclass code (not shown)	1 byte	1	Read	0x00
0x0B	Class code	1 byte	1	Read	mode-dependent 0x06 host 0x0E agent
0x0C	Cache line size	1 byte	1	Read/Write	0x00
0x0D	Latency timer	1 byte	1	Read/Write	0x00

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Table 4-2. MPC8240 Configuration Registers Accessible from the Processor Core (Continued)

Address Offset	Register	Size	Program Access Size (Bytes)	Access	Reset Value
0x0E	Header type (not shown)	1 byte	1	Read	0x00
0x0F	BIST control	1 byte	1	Read	0x00
0x10	Local memory base address register	4 bytes	4	Read/Write	0x0000_0008
0x14	Peripheral control and status register base address register	4 bytes	4	Read/Write	0x0000_0000
0x30	Expansion ROM base address	4 bytes	4	Read	0x0000_0000
0x3C	Interrupt line	1 byte	1	Read/Write	0x00
0x3D	Interrupt pin (not shown)	1 byte	1	Read	0x01
0x3E	MIN GNT (not shown)	1 byte	1	Read	0x00
0x3F	MAX LAT (not shown)	1 byte	1	Read	0x00
0x40	Bus number (not shown)	1 byte	1	Read/Write	0x00
0x41	Subordinate bus number (not shown)	1 byte	1	Read/Write	0x00
0x46	PCI arbiter control register	2 bytes	2	Read/Write	0x0000
0x70	Power management configuration register 1 (PMCR1)	2 bytes	1 or 2	Read/Write	0x00
0x72	Power management configuration register 2 (PMCR2)	1 byte	1	Read/Write	0x00
0x73	Output driver control register	1 byte	1	Read/Write	0xFF
0x74	CLK driver control register	2 bytes	1 or 2	Read/Write	0x0300
0x78	Embedded utilities memory block base address register	4 bytes	4 bytes	Read/Write	0x0000_0000
0x80, 0x84	Memory starting address registers	4 bytes	1, 2, or 4	Read/Write	0x0000_0000
0x88,0x 8C	Extended memory starting address registers	4 bytes	1, 2, or 4	Read/Write	0x0000_0000
0x90, 0x94	Memory ending address registers	4 bytes	1, 2, or 4	Read/Write	0x0000_0000
0x98, 0x9C	Extended memory ending address registers	4 bytes	1, 2, or 4	Read/Write	0x0000_0000
0xA0	Memory bank enable register	1 byte	1	Read/Write	0x00
0xA3	Page mode counter/timer	1 byte	1	Read/Write	0x00
0xA8	Processor interface configuration 1	4 bytes	1, 2, or 4	Read/Write	0xFF04_0010
0xAC	Processor interface configuration 2	4 bytes	1, 2, or 4	Read/Write	0x000C_000C
0xB8	ECC single bit error counter	1 byte	1	Read/Write	0x00
0xB9	ECC single bit error trigger register	1 byte	1	Read/Write	0x00
0xC0	Error enabling register 1	1 byte	1	Read/Write	0x01
0xC1	Error detection register 1	1 byte	1	Read/Bit Reset	0x00

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Table 4-2. MPC8240 Configuration Registers Accessible from the Processor Core (Continued)

Address Offset	Register	Size	Program Access Size (Bytes)	Access	Reset Value
0xC3	Processor internal bus error status register	1 byte	1	Read/Bit Reset	0x00
0xC4	Error enabling register 2	1 byte	1	Read/Write	0x00
0xC5	Error detection register 2	1 byte	1	Read/Bit Reset	0x00
0xC7	PCI bus error status register	1 byte	1	Read/Bit Reset	0x00
0xC8	Processor/PCI error address register	4 byte	1, 2, or 4	Read	0x00
0xE0	Address map B options register	1 byte	1	Read/Write	0xC0
0xF0	MCCR1	4 bytes	1, 2, or 4	Read/Write	0xFFn2_0000
0xF4	MCCR2	4 bytes	1, 2, or 4	Read/Write	0x0000_0000
0xF8	MCCR3	4 bytes	1, 2, or 4	Read/Write	0x0000_0000
0xFC	MCCR4	4 bytes	1, 2, or 4	Read/Write	0x0000_0000
others	Reserved	—	—	—	—

Note: Reset values marked mode-dependent are defined by whether the MPC8240 is operating in host or agent mode.

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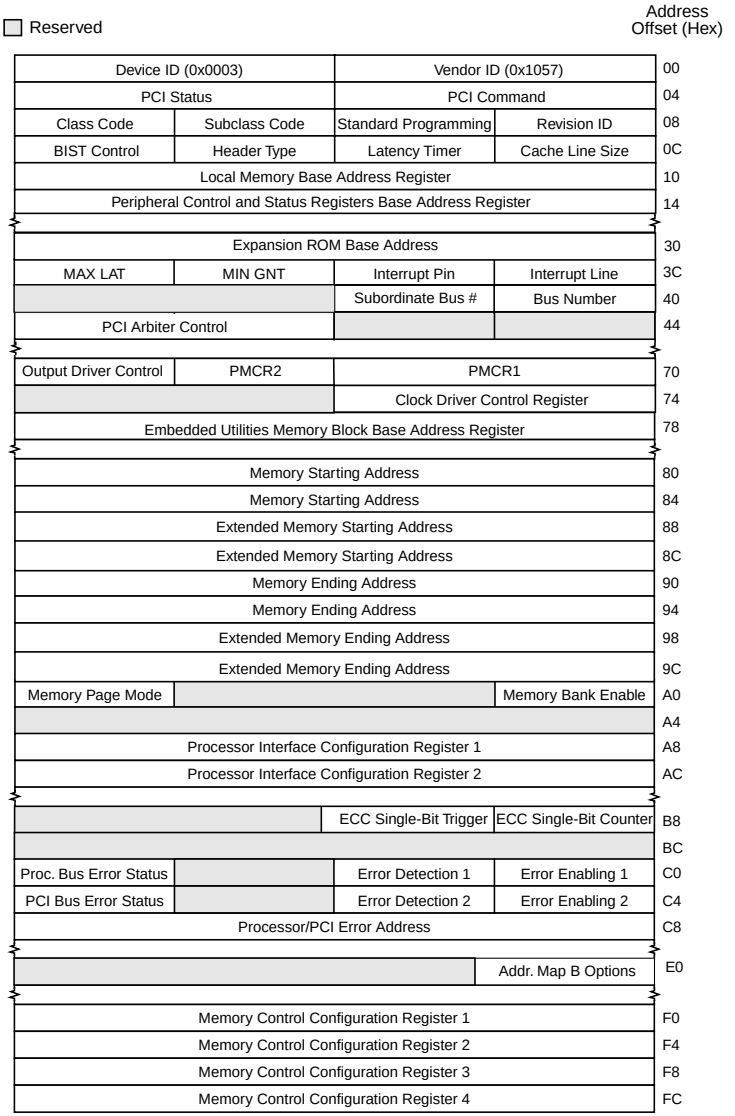

Figure 4-1. Processor Accessible Configuration Space

4.1.3.2 PCI-Accessible Configuration Registers

Table 4-3 lists the subset of configuration registers that are accessible from the PCI bus. Note that configuration addresses not defined in Table 4-3 are reserved.

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Table 4-3. MPC8240 Configuration Registers Accessible from the PCI Bus

Address Offset	Register	Size	Program Access Size (Bytes)	Access	Reset Value
0x00	Vendor ID = 0x1057	2-bytes	2	Read	0x1057
0x02	Device ID = 0x0003	2-bytes	2	Read	0x0003
0x04	PCI command register	2-bytes	2	Read/Write	mode-dependent 0x0004 host 0x0000 agent
0x06	PCI status register	2-bytes	2	Read/Bit-Reset	0x00A0
0x08	Revision ID	1-byte	1	Read	0xnn
0x09	Standard programming interface	1-byte	1	Read	mode-dependent 0x00 host 0x01 agent
0x0A	Subclass code	1-byte	1	Read	0x00
0x0B	Class code	1-byte	1	Read	mode-dependent 0x06 host 0x0E agent
0x0C	Cache line size	1-byte	1	Read/Write	0x00
0x0D	Latency timer	1-byte	1	Read/Write	0x00
0x0E	Header type	1-byte	1	Read	0x00
0x0F	BIST control	1-byte	1	Read	0x00
0x10	Local memory base address register	4-bytes	4	Read/Write	0x0000_0008
0x14	Peripheral control and status register base address register	4-bytes	4	Read/Write	0x0000_0000
0x30	Expansion ROM base address	4 bytes	4	Read	0x0000_0000
0x3C	Interrupt line	1-byte	1	Read/Write	0x00
0x3D	Interrupt pin	1-byte	1	Read	0x01
0x3E	MIN GNT	1-byte	1	Read	0x00
0x3F	MAX LAT	1-byte	1	Read	0x00
0x46	PCI arbiter control register	2-bytes	2	Read/Write	0x0000
Others	Reserved	—	—	—	—

Note: Reset values marked mode-dependent are defined by whether the MPC8240 is operating in host or agent mode.

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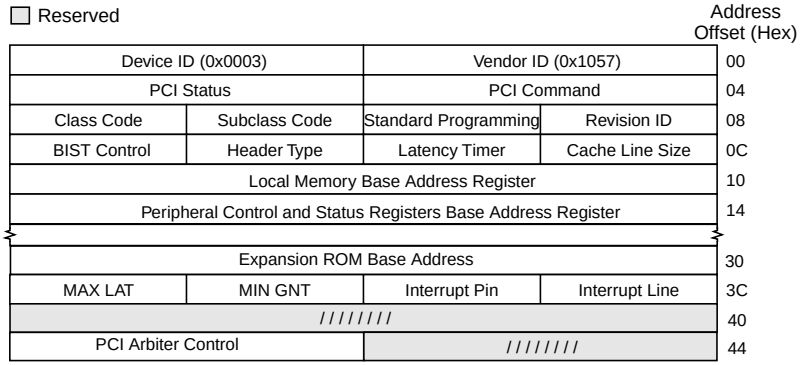

Figure 4-2. PCI Accessible Configuration Space

4.2 PCI Interface Configuration Registers

The *PCI Local Bus Specification* defines the configuration registers from 0x00 through 0x3F. Table 4-4 summarizes the PCI configuration registers of the MPC8240. Detailed descriptions of these registers are provided in the *PCI Local Bus Specification.*

Table 4-4. PCI Configuration Space Header Summary

Address Offset	Register Name	Description
0x00	Vendor ID	Identifies the manufacturer of the device (0x1057 = Motorola)
0x02	Device ID	Identifies the particular device (0x0003 = MPC8240)
0x04	PCI command	Provides coarse control over a device's ability to generate and respond to PCI bus cycles (see Section 4.2.1, "PCI Command Register—Offset 0x04," for more information)
0x06	PCI status	Records status information for PCI bus-related events (see Section 4.2.2, "PCI Status Register—Offset 0x06," for more information)
0x08	Revision ID	Specifies a device-specific revision code (assigned by Motorola)
0x09	Standard programming interface	Identifies the register-level programming interface of the MPC8240 (0x00)
0x0A	Subclass code	Identifies more specifically the function of the MPC8240 (0x00 = host bridge)
0x0B	Base class code	Broadly classifies the type of function the MPC8240 performs (0x06 = bridge device)
0x0C	Cache line size	Specifies the system cache line size
0x0D	Latency timer	Specifies the value of the latency timer for this bus master in PCI bus clock units
0x0E	Header type	Bits 0–6 identify the layout of bytes 10–3F; bit 7 indicates a multifunction device. The MPC8240 uses the most common header type (0x00).
0x0F	BIST control	Optional register for control and status of built-in self test (BIST)
0x10–0x2F	—	Reserved on the MPC8240

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Table 4-4. PCI Configuration Space Header Summary (Continued)

Address Offset	Register Name	Description
0x30	Expansion ROM base address	This register is read-only. The default value has 0b0 in bit 0, defining the expansion ROM base address register as disabled in the MPC8240.
0x34–0x3B	—	Reserved for future use by PCI
0x3C	Interrupt line	Contains interrupt line routing information
0x3D	Interrupt pin	Indicates which interrupt pin the device (or function) uses (0x00 = no interrupt pin)
0x3E	MIN GNT	Specifies the length of the device's burst period (0x00 indicates that the MPC8240 has no major requirements for the settings of latency timers.)
0x3F	MAX LAT	Specifies how often the device needs to gain access to the PCI bus (0x00 indicates that the MPC8240 has no major requirements for the settings of latency timers)
0x43	—	Reserved on the MPC8240

System software may need to scan the PCI bus to determine what devices are actually present. To do this, the configuration software must read the vendor id in each possible PCI slot. If there is no response to a read of an empty slot, the MPC8240 returns 0xFFFF (the invalid vendor id). Any configuration write cycle to a reserved register is completed normally and the data is discarded.

Note that the MPC8240 must not issue PCI configuration transactions to itself (that is, for PCI configuration transactions initiated by the MPC8240, its IDSEL input signal must not be asserted).

4.2.1 PCI Command Register—Offset 0x04

The following subsections describe the MPC8240 PCI configuration registers in detail.

The 2-byte PCI command register, shown in Figure 4-3, provides control over the ability to generate and respond to PCI cycles. Table 4-5 describes the bits of the PCI command register.

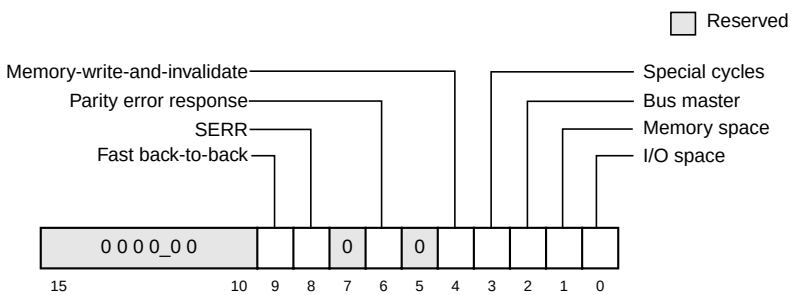

Figure 4-3. PCI Command Register—0x04

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The 2-byte PCI status register, shown in Figure 4-4, is used to record status information for PCI bus-related events. The definition of each bit is given in Table 4-6. Only 2-byte accesses to address offset 0x06 are allowed.

Table 4-5. Bit Settings for PCI Command Register—0x04

Bits	Name	Reset Value	Description
15–10	—	All 0s	These bits are reserved.
9	Fast back-to-back	0	This bit is hardwired to 0, indicating that the MPC8240 does not run fast back-to-back transactions.
8	SERR	0	This bit controls the $\overline{\text{SERR}}$ driver of the MPC8240. This bit (and bit 6) must be set to report address parity errors. 0 Disables the $\overline{\text{SERR}}$ driver 1 Enables the $\overline{\text{SERR}}$ driver
7	—	0	This bit is reserved.
6	Parity error response	0	This bit controls whether the MPC8240 responds to parity errors. 0 Parity errors are ignored and normal operation continues. 1 Action is taken on a parity error. See Chapter 13, “Error Handling,” for more information.
5	—	0	This bit is reserved.
4	Memory-write-and-invalidate	0	This bit enables generation of the memory-write-and-invalidate command by the MPC8240 as a master. 0 Memory-write command used by MPC8240. 1 Memory-write-and-invalidate command used by MPC8240.
3	Special cycles	0	This bit is hardwired to 0, indicating that the MPC8240 (as a target) ignores all special-cycle commands.
2	Bus master	1 (host) 0 (agent)	This bit controls whether the MPC8240 can act as a master on the PCI bus. Note that if this bit is cleared, processor-to-PCI writes cause the data to be held until it is enabled. Processor to PCI reads with master disabled cause a machine check exception (if enabled). 0 Disables the ability to generate PCI accesses 1 Enables the MPC8240 to behave as a PCI bus master
1	Memory space	0	This bit controls whether the MPC8240 (as a target) responds to memory accesses. 0 The MPC8240 does not respond to PCI memory space accesses. 1 The MPC8240 responds to PCI memory space accesses.
0	I/O space	0	This bit is hardwired to 0, indicating that the MPC8240 (as a target) does not respond to PCI I/O space accesses.

4.2.2 PCI Status Register—Offset 0x06

The 2-byte PCI status register, shown in Figure 4-4, is used to record status information for PCI bus-related events. The definition of each bit is given in Table 4-6. Only 2-byte accesses to address offset 0x06 are allowed.

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Reads to this register behave normally. Writes are slightly different in that bits can be cleared, but not set. A bit is cleared whenever the register is written, and the data in the corresponding bit location is a 1. For example, to clear bit 14 and not affect any other bits in the register, write the value 0b0100_0000_0000_0000 to the register.

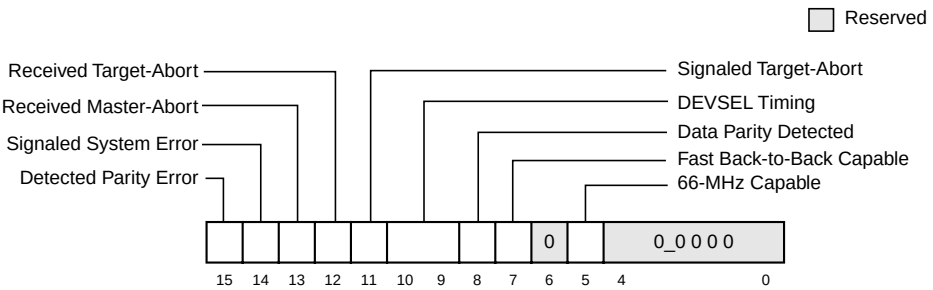

Figure 4-4. PCI Status Register—0x06

Table 4-6 describes the bit settings for the PCI status register.

Table 4-6. Bit Settings for PCI Status Register—0x06

Bits	Name	Reset Value	Description
15	Detected parity error	0	This bit is set whenever the MPC8240 detects an address or data parity error, even if parity error handling is disabled (as controlled by bit 6 in the PCI command register).
14	Signaled system error	0	This bit is set whenever the MPC8240 asserts $\overline{\text{SERR}}$.
13	Received master-abort	0	This bit is set whenever the MPC8240, acting as the PCI master, terminates a transaction (except for a special-cycle) using master-abort.
12	Received target-abort	0	This bit is set whenever an MPC8240-initiated transaction is terminated by a target-abort.
11	Signaled target-abort	0	This bit is set whenever the MPC8240, acting as the PCI target, issues a target-abort to a PCI master.
10–9	DEVSEL timing	00	These bits are hardwired to 0b00, indicating that the MPC8240 uses fast device select timing.
8	Data parity detected	0	This bit is set upon detecting a data parity error. Three conditions must be met for this bit to be set: • The MPC8240 detected a parity error. • MPC8240 was acting as the bus master for the operation in which the error occurred. • Bit 6 (parity error response) in the PCI command register was set.
7	Fast back-to-back capable	1	This bit is hardwired to 1, indicating that the MPC8240 (as a target) is capable of accepting fast back-to-back transactions.
6	—	0	This bit is reserved.
5	66-MHz capable	1	This bit is read-only and indicates that the MPC8240 is capable of 66-MHz PCI bus operation.
4–0	—	0_0000	These bits are reserved.

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4.2.3 Programming Interface—Offset 0x09

Table 4-7 describes the PCI programming interface register (PIR).

Table 4-7. Programming Interface—0x09

Bits	Reset Value	Description
msb 7–0	Mode-dependent	0x00 When MPC8240 is configured as host bridge 0x01 When MPC8240 is configured as an agent device to indicate the programming model supports the I_2O interface

4.2.4 PCI Base Class Code—Offset 0x0B

Table 4-8 describes the PCI base class code register (PBCCR).

Table 4-8. PCI Base Class Code—0x0B

Bits	Reset Value	Description
msb 7–0	Mode-dependent	0x06 When MPC8240 is configured as a host bridge to indicate “Host Bridge.” 0x0E When MPC8240 is configured as a target device to indicate the device is an agent and is I_2O capable.

4.2.5 PCI Cache Line Size—Offset 0x0C

Table 4-9 describes the processor cache line size register (PCLSR).

Table 4-9. Cache Line Size Register—0x0C

Bits	Reset Value	Description
msb 7–0	0x00	Represents the cache line size of the processor in terms of 32-bit words (eight 32-bit words = 32 bytes). This register is read-write; however, an attempt to program this register to any value other than 8 results in setting it to 0.

4.2.6 Latency Timer—Offset 0x0D

Table 4-10 describes the PCI latency timer register (PLTR).

Table 4-10. Latency Timer Register—0x0D

Bits	Reset Value	Description
msb 7–3	0000_0	The maximum number of PCI clocks for which the MPC8240, which is mastering a transaction, will hold the bus after the PCI bus grant has been negated. The entire value in this register represents the total latency in PCI clocks. Thus the total latency is the value in bits 7–3 multiplied by 8 (because bits 2–0 are read-only as zeros). Refer to the PCI 2.1 specification for the rules by which the PCI bus interface unit completes transactions when the timer has expired.
2–0	000	Read-only bits—Because these bits are read-only as zeros, the granularity of the latency timer value is 8 PCI clocks.

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4.2.7 PCI Base Address Registers—LMBAR and PCSRBAR

Two base address registers are provided when the MPC8240 is used in the PCI agent mode:

- Local memory base address register (LMBAR)
- Peripheral control and status registers base address register (PCSRBAR)

These registers allow a host processor to configure the base addresses of the MPC8240 when the MPC8240 is being used as a PCI agent. The use of these memory spaces is optional and therefore selectable by the processor. It is expected that the processor core configures the local memory and enables the embedded utilities prior to the host software being allowed to complete PCI configuration. See Chapter 3, "Address Maps," for more information on the use of the embedded utilities and the address translation functionality of the MPC8240.

Table 4-11 describes the bits of the LMBAR.

Table 4-11. Local Memory Base Address Register Bit Definitions—0x10

Bits	Name	Reset Value	R/W	Description
31–12	Inbound memory base address	0x0000_0	R/W	Indicates the base address where the inbound memory window resides. The inbound memory window should be aligned based on the granularity specified by the inbound window size specified in the ITWR. Note that the EUMB area must be selected first, then the ITWR programmed, and then the bits set. Refer to Chapter 3, "Address Maps," for more information on the EUMB and the ATU.
11–4	Reserved	All 0s	R	Reserved; the MPC8240 only allows a minimum of a 4-Kbyte window.
3	Prefetchable	1	R	Indicates that the space is prefetchable.
2–1	Type	00	R	The inbound memory window may be located anywhere within the 32-bit PCI address space.
0	Memory space indicator	0	R	Indicates PCI memory space

Table 4-12 describes the PCSRBAR.

Table 4-12. PCSR Base Address Register Bit Definitions—0x14

Bits	Reset Value	R/W	Description
msb 31–12	0x0000_0	R/W	Indicates the PCI base address that is mapped to the runtime registers (for example, DMA, I_2O).
11–0	0x000	R	Reserved

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4.2.8 PCI Interrupt Line—Offset 0x3C

Table 4-13 describes the PCI interrupt line register (ILR).

Table 4-13. Interrupt Line Register—0x3C

Bits	Reset Value	Description
msb 7–0	0x00	Contains the interrupt routing information. Software can use this register to hold information regarding on which input of the system interrupt controller corresponds to the $\overline{\text{INTA}}$ signal. Values in this register are system-architecture-specific.

4.2.9 PCI Arbiter Control Register (PACR)—Offset 0x46

This register controls the on-chip arbitration for external PCI masters. As many as five external devices are supported.

Table 4-14. PCI Arbiter Control Register Bit Definitions—0x46

Bits	Reset Value	R/W	Description
msb 15	x	R/W	Enable on-chip PCI arbitration 0 If cleared, the on-chip arbiter for external PCI masters is disabled, and the MPC8240 presents its request on $\overline{\text{GNT0}}$ to the external arbiter and receives its grant on $\overline{\text{REQ0}}$. 1 If set, indicates the on-chip arbiter is enabled.
14–13	00	R/W	Parking mode controls which device receives the bus grant when there are no outstanding bus requests and the bus is idle. 00 The bus is parked with the last device to use the bus. 01 The bus is parked with the device using $\overline{\text{REQ0}}$ and $\overline{\text{GNT0}}$. 10 The bus is parked with MPC8240. 11 Reserved; do not use.
12	0	R/W	PCI broken master disable. This bit controls whether the PCI arbiter negates the bus grant to a requesting master that does not assert $\overline{\text{FRAME}}$ within 16 PCI clock cycles from the time the bus is idle. 0 PCI arbiter negates the PCI $\overline{\text{GNTx}}$ signal to a requesting master that does not begin using the bus (by asserting FRAME) within 16 PCI clock cycles from the time the PCI clock is idle. 1 A PCI master that has been granted the bus never loses its grant until (and unless) it begins a transaction or negates the $\overline{\text{REQx}}$ signal. It is recommended that this bit stay cleared.
11	0	R	Reserved
10	0	R/W	Retry PCI Configuration Cycle 1 PCI target logic retries all external PCI configuration transactions. 0 PCI target logic responds to external PCI configuration transactions.
9–8	00	R	Reserved
7	0	R/W	MPC8240 priority level, 1 = high, 0 = low
6–5	00	R	Reserved
4–0	0_0000	R/W	External device priority levels, 1 = high, 0 = low. Bit 0 corresponds to the device using $\overline{\text{REQ0}}$ and $\overline{\text{GNT0}}$, bit 1 to $\overline{\text{REQ1}}$ and $\overline{\text{GNT1}}$, etc.

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4.3 Peripheral Logic Power Management Configuration Registers (PMCRs)

The power management configuration registers (PMCRs) control the power management functions of the peripheral logic. For more information on the power management feature of both the processor core and the peripheral logic, see Chapter 14, “Power Management.”

4.3.1 Power Management Configuration Register 1 (PMCR1)—Offset 0x70

Power management configuration register 1 (PMCR1), shown in Figure 4-5, is a 2-byte register located at offset 0x70.

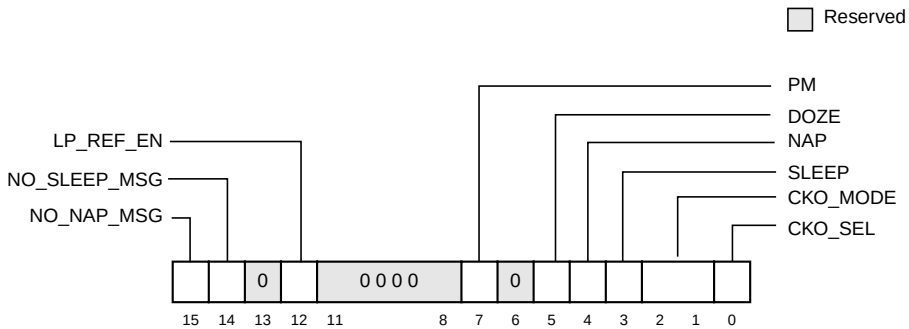

Figure 4-5. Power Management Configuration Register 1 (PMCR1)—0x70

Table 4-15 describes the bits of PMCR1.

Table 4-15. Bit Settings for Power Management Configuration Register 1—0x70

Bits	Name	Reset Value	Description
15	NO_NAP_MSG	0	HALT command broadcast—Not supported on the MPC8240. 1 Initialization software must set this bit, indicating that the MPC8240 does not broadcast a HALT command on the PCI bus before entering the nap mode.
14	NO_SLEEP_MSG	0	Sleep message broadcast.—Not supported on the MPC8240. 1 Initialization software must set this bit, indicating that the MPC8240 does not broadcast a sleep message command on the PCI bus before entering the sleep mode.
13	—	0	Reserved
12	LP_REF_EN	0	Low-power refresh 0 Indicates that the MPC8240 does not perform memory refresh cycles when it is in sleep mode 1 Indicates that the MPC8240 continues to perform memory refresh cycles when in sleep mode

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Table 4-15. Bit Settings for Power Management Configuration Register 1—0x70 (Continued)

Bits	Name	Reset Value	Description
11–8	—	0	Reserved
7	PM	0	Power management enable 0 Disables the peripheral logic power management logic within the MPC8240 1 Enables the peripheral logic power management logic within the MPC8240
6	—	0	Reserved
5	DOZE	0	Enables/disables the doze mode capability of the MPC8240. Note that this bit is only valid if MPC8240 power management is enabled. (PMCR1[PM] = 1). 0 Disables the doze mode 1 Enables the doze mode
4	NAP	0	Enables/disables the nap mode capability of the MPC8240. Note that this bit is only valid if MPC8240 power management is enabled. (PMCR1[PM] = 1). 0 Disables the nap mode 1 Enables the nap mode
3	SLEEP	0	Enables/disables the sleep mode capability of the MPC8240. Note that this bit is only valid if MPC8240 power management is enabled (PMCR1[PM] = 1). 0 Disables the sleep mode 1 Enables the sleep mode
2–1	CKO_MODE	00	Selects the clock source for the test clock output when CKO_SEL = 1. 00 Disables the test clock output driver 01 Selects the internal sys_logic_clk signal as the test clock output source 10 Selects one-half of the PCI rate clock as the test clock output source 11 Selects the internal PCI rate clock as the test clock output source
0	CKO_SEL	x	The initial value of this bit is determined by the $\overline{AS}$ reset configuration bit, which selects either the clock output of the processor core or the clock output of the system logic to be driven out of the CKO signal. 0 Processor core clock selected. The signal driven by CKO is determined by HID0[ECLK,SBCLK]. See Section 5.3.1.2.1, “Hardware Implementation-Dependent Register 0 (HID0),” for the available choices. 1 System logic clock selected. The signal driven by CKO is determined by the encoding of the CKO_MODE bits above. See CKO_MODE field description for the available choices.

4.3.2 Power Management Configuration Register 2 (PMCR2)—Offset 0x72

Power management configuration register 2 (PMCR2), shown in Figure 4-6, is a 1-byte register located at offset 0x72.

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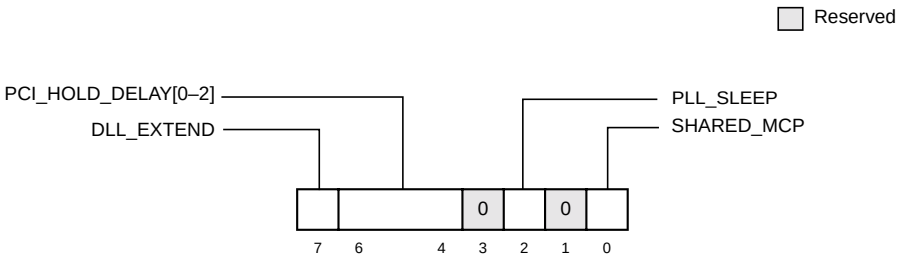

Figure 4-6. Power Management Configuration Register 2 (PMCR2)—0x72

Table 4-16 describes the bits of PMCR2.

Table 4-16. Power Management Configuration Register 2—0x72

Bits	Name	Reset Value	Description
msb 7	DLL_EXTEND	0	This bit can be used to shift the lock-range of the DLL by half of a PCI clock cycle. See the MPC8240 Hardware Specification for more information on the use of the DLL extend feature. 0 DLL extended range 1 Standard (non-extended) range
6–4	PCI_HOLD_DEL	xx0	PCI output hold delay value relative to the PCI_SYNC_IN signal. See the MPC8240 Hardware Specification for the detailed number of nanoseconds guaranteed for each setting. There are eight sequential settings for this value; each corresponds to a set increase in hold time: 000 Recommended for 66 MHz PCI bus 001 010 011 100 Recommended for 33 MHz PCI bus 101 110 Default if reset configuration pins left unconnected 111 The initial values of bits 6 and 5 are determined by the $\overline{\text{MCP}}$ and CKE reset configuration signals, respectively. See Section 2.4, “Configuration Signals Sampled at Reset,” for more information. As these two pins have internal pull-up resistors, the default value after reset is 0b110.
3	—	0	Reserved
2	PLL_SLEEP	0	PLL sampling when waking from sleep mode 0 The MPC8240 does not sample the PLL configuration pins 1 The MPC8240 samples the PLL configuration pins
1	—	0	Reserved
0	SHARED_MCP	0	0 The $\overline{\text{MCP}}$ output is always driven (asserted if there is an error to report; negated otherwise) by the MPC8420. 1 The $\overline{\text{MCP}}$ output signal is tri-stated when there is no error to report by the MPC8240.

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4.4 Output/Clock Driver and Miscellaneous I/O Control Registers

Table 4-17 describes the general output driver control available with the MPC8240 through the output driver control register (ODCR), and Table 4-18 describes the output enable/disable capability available for the clock signals through the clock driver control register (CDCR).

Output driver control allows for impedance matching of electrical signals. When driving a capacitive load and the polarity of the driving signal is reversed, the maximum current driven by the output driver of a pin occurs during the transition of the signal. The output driver strength must be configured to match the load impedance. The matched impedance limits the maximum current driven during signal transitions. The transition current and mismatched impedance cause ringing on the signal. If the driver level is set too strong, the ringing intensifies. For more information on the output driver type for each signal, refer to the *MPC8240 Hardware Specification.*

Table 4-17. Output Driver Control Register Bit Definitions—0x73

Bits	Name	Reset Value	Description
msb 7 addr<73>	DRV_PCI	x	Driver capability for PCI and EPIC controller output signals. The initial value of this bit is determined by the PMAA2reset configuration pin. 0 High drive capability on PCI signals (25 Ω) 1 Medium drive capability on PCI signals (50 Ω)
6	DRV_STD	1	Driver capability for standard signals (SDA, SCL, CKO, $\overline{\text{QACK}}$, $\overline{\text{MIV}}$, PMAA[0:2], and $\overline{\text{MCP}}$). 0 High drive capability on standard signals (20 Ω) 1 Medium drive capability on standard signals (40 Ω)
5	DRV_MEM_CTRL_1	x	Driver capability for the MDH[0:31], MDL[0:31], PAR[0:7], MAA[0:2], and $\overline{\text{RCS1}}$ signals. Controlled in combination with DRV_MEM_CTRL_2, as follows: 1 20-Ω data bus drive capability; when this is selected, only 8-Ω or 13.3-Ω drive capability allowed for DRV_MEM_CTRL_2 0 40-Ω data bus drive capability, when this is selected, only 20-Ω or 40-Ω drive capability allowed for DRV_MEM_CTRL_2

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Table 4-17. Output Driver Control Register Bit Definitions—0x73 (Continued)

Bits	Name	Reset Value	Description
4	DRV_MEM_CTRL_2	x	Driver capability for address signals ($\overline{RAS}$/$\overline{CS}$[0:7], $\overline{CAS}$/DQM[0:7], $\overline{WE}$, $\overline{FOE}$, $\overline{RCS0}$, SDBA0, AR[19:12], $\overline{SDRAS}$, $\overline{SDCAS}$, CKE, $\overline{AS}$, SDMA[12:0]). The meaning of this bit setting depends on the setting of DRV_MEM_CTRL_1. The two bits and the meaning of their combined settings for the address signals are shown below: DRV_MEM_CTRL_[1–2]: 11 8-Ω drive capability 10 13.3-Ω drive capability 01 20-Ω drive capability 00 40-Ω drive capability The initial value of DRV_MEM_CTRL[1–2] is determined by the PMAA0 and PMAA1 reset configuration pins, respectively.
3	DRV_PCI_CLK_1	1	Driver capability is controlled in combination with DRV_PCI_CLK_2 as shown.
2	DRV_PCI_CLK_2	1	Driver capability is controlled in combination with DRV_PCI_CLK_1, and controls drive strength of PCI_CLK[0:4] and PCI_CLK_SYNC_OUT. DRV_PCI_CLK_[1–2]: 11 8-Ω drive capability 10 13.3-Ω drive capability 01 20-Ω drive capability 00 40-Ω drive capability
1	DRV_MEM_CLK_1	1	Driver capability is controlled in combination with DRV_MEM_CLK_2 as shown.
0	DRV_MEM_CLK_2	1	Driver capability is controlled in combination with DRV_MEM_CLK_1, and controls drive strength of SDRAM_CLK[0:3] and SDRAM_SYNC_OUT. DRV_MEM_CLK_[1–2]: 11 8-Ω drive capability 10 13.3-Ω drive capability 01 20-Ω drive capability 00 40-Ω drive capability

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Table 4-18. CLK Driver Control Register Bit Definitions—0x74

Bit	Name	Reset Value	Description
15 addr<75>	—	x	Reserved
14	PCI_CLK0_DIS	0	This bit disables/enables the PCI_CLK0 output of MPC8420. A value of one (0b1) disables the output. A value of zero (0b0) enables the output.
13	PCI_CLK1_DIS	0	This bit disables/enables the PCI_CLK1 output of MPC8420. A value of one (0b1) disables the output. A value of zero (0b0) enables the output.
12	PCI_CLK2 _DIS	0	This bit disables/enables the PCI_CLK2 output of MPC8420. A value of one (0b1) disables the output. A value of zero (0b0) enables the output.
11	PCI_CLK3_DIS	0	This bit disables/enables the PCI_CLK3 output of MPC8420. A value of one (0b1) disables the output. A value of zero (0b0) enables the output.
10	PCI_CLK4_DIS	0	This bit disables/enables the PCI_CLK4 output of MPC8420. A value of one (0b1) disables the output. A value of zero (0b0) enables the output.
9–8	—	00	Reserved
7 addr<74>	—	x	Reserved
6	SDRAM_CLK0_DIS	0	This bit disables/enables the SDRAM_CLK0 output of MPC8420. A value of one (0b1) disables the output. A value of zero (0b0) enables the output.
5	SDRAM_CLK1_DIS	0	This bit disables/enables the SDRAM_CLK1 output of MPC8420. A value of one (0b1) disables the output. A value of zero (0b0) enables the output.
4	SDRAM_CLK2_DIS	0	This bit disables/enables the SDRAM_CLK2 output of MPC8420. A value of one (0b1) disables the output. A value of zero (0b0) enables the output.
3	SDRAM_CLK3_DIS	0	This bit disables/enables the SDRAM_CLK3 output of MPC8420. A value of one (0b1) disables the output. A value of zero (0b0) enables the output.
2–0	—	000	Reserved

4.5 Embedded Utilities Memory Block Base Address Register—0x78

The embedded utilities memory block base address register (EUMBBAR), shown in Table 4-19, controls the placement of the embedded utilities memory block (EUMB). See Section 3.4, “Embedded Utilities Memory Block (EUMB).”

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Table 4-19. Embedded Utilities Memory Base Address Register—0x78

Bits	Name	Reset Value	Description
msb 31–20	Base Address	0x000	Base address of the embedded memory utilities block. The block size is 1 Mbyte, and its base address is aligned naturally to a 1 Mbyte address boundary (so the base address is 0xXXX0_0000). This block is used by processor-initiated transactions and should be located within PCI memory space. Registers within the EUMB are located from 0x8000_0000 to 0xFDFF_FFFF. Thus, valid values are 0x800–0xFDF. Otherwise, the EUMB is effectively disabled.
19–0	—	0x0_0000	Reserved

4.6 Memory Interface Configuration Registers

The memory interface configuration registers (MICRs) control memory boundaries (starting and ending addresses), memory bank enables, memory timing, and external memory buffers. Initialization software must program the MICRs at reset and then enable the memory interface on the MPC8240 by setting the MEMGO bit in memory control configuration register 1 (MCCR1).

4.6.1 Memory Boundary Registers

The extended starting address and the starting address registers are used to define the lower address boundary for each memory bank. The lower boundary is determined by the following formula:

Lower boundary for bank n = 0b00 || <extended starting address n> || <starting address n> || 0x0_0000.

The extended ending address and the ending address registers are used to define the upper address boundary for each memory bank. The upper boundary is determined by the following formula:

Upper boundary for bank n = 0b00 || <extended ending address n> || <ending address n> || 0xF_FFFF.

Figure 4-7, Figure 4-8, and Table 4-20 depict the memory starting address register 1 and 2 bit settings.

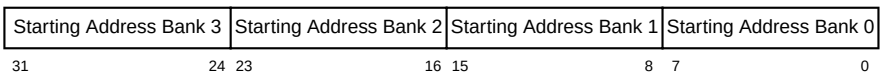

Figure 4-7. Memory Starting Address Register 1—0x80

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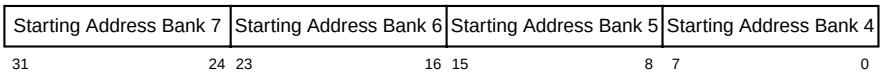

Figure 4-8. Memory Starting Address Register 2—0x84

Table 4-20. Bit Settings for Memory Starting Address Registers 1 and 2

Bits	Name	Reset Value	Description	Word Address
31–24	Starting address bank 3	0x00	Starting address for bank 3	0x80
23–16	Starting address bank 2	0x00	Starting address for bank 2	
15–8	Starting address bank 1	0x00	Starting address for bank 1	
7–0	Starting address bank 0	0x00	Starting address for bank 0	
31–24	Starting address bank 7	0x00	Starting address for bank 7	0x84
23–16	Starting address bank 6	0x00	Starting address for bank 6	
15–8	Starting address bank 5	0x00	Starting address for bank 5	
7–0	Starting address bank 4	0x00	Starting address for bank 4	

Figure 4-9, Figure 4-10, and Table 4-21 depict the extended memory starting address register 1 and 2 bit settings.

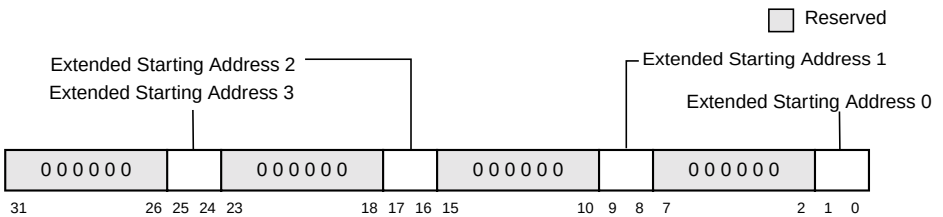
Reserved
Extended Starting Address 2
Extended Starting Address 3
Extended Starting Address 1
Extended Starting Address 0
0 0 0 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0
31
26 25 24 23
18 17 16 15
10 9 8 7
2 1 0

Figure 4-9. Extended Memory Starting Address Register 1—0x88.

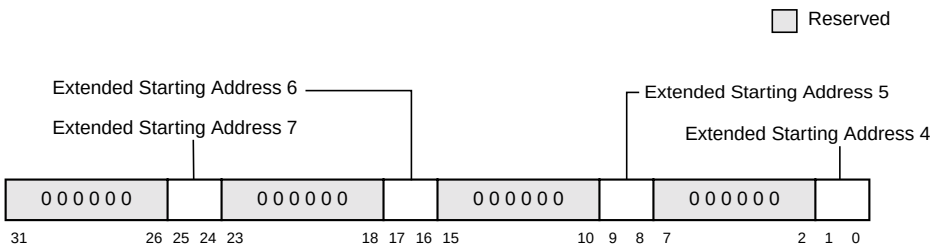
Reserved
Extended Starting Address 6
Extended Starting Address 7
Extended Starting Address 5
Extended Starting Address 4
0 0 0 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0
0 0 0 0 0 0
31
26 25 24 23
18 17 16 15
10 9 8 7
2 1 0

Figure 4-10. Extended Memory Starting Address Register 2—0x8C

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Table 4-21. Bit Settings for Extended Memory Starting Address Registers 1 and 2

Bits	Name	Reset Value	Description	Byte Address
31–26	—	All 0s	Reserved	0x88
25–24	Extended starting address 3	0b00	Extended starting address for bank 3	
23–18	—	All 0s	Reserved	
17–16	Extended starting address 2	0b00	Extended starting address for bank 2	
15–10	—	All 0s	Reserved	
9–8	Extended starting address 1	0b00	Extended starting address for bank 1	
7–2	—	All 0s	Reserved	
1–0	Extended starting address 0	0b00	Extended starting address for bank 0	
31–26	—	All 0s	Reserved	0x8C
25–24	Extended starting address 7	0b00	Extended starting address for bank 7	
23–18	—	All 0s	Reserved	
17–16	Extended starting address 6	0b00	Extended starting address for bank 6	
15–10	—	All 0s	Reserved	
9–8	Extended starting address 5	0b00	Extended starting address for bank 5	
7–2	—	All 0s	Reserved	
1–0	Extended starting address 4	0b00	Extended starting address for bank 4	

Figure 4-11, Figure 4-12, and Table 4-22 depict the memory ending address register 1 and 2 bit settings.

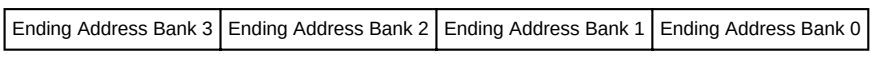

Figure 4-11. Memory Ending Address Register 1—0x90

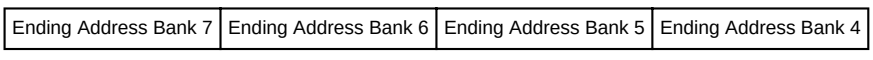

Figure 4-12. Memory Ending Address Register 2—0x94

Table 4-22. Bit Settings for Memory Ending Address Registers 1 and 2

Bits	Name	Reset Value	Description	Byte Address
31–24	Ending address bank 3	0x00	Ending address for bank 3	0x90
23–16	Ending address bank 2	0x00	Ending address for bank 2	
15–8	Ending address bank 1	0x00	Ending address for bank 1	
7–0	Ending address bank 0	0x00	Ending address for bank 0	

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Table 4-22. Bit Settings for Memory Ending Address Registers 1 and 2 (Continued)

Bits	Name	Reset Value	Description	Byte Address
31–24	Ending address bank 7	0x00	Ending address for bank 7	0x94
23–16	Ending address bank 6	0x00	Ending address for bank 6	
15–8	Ending address bank 5	0x00	Ending address for bank 5	
7–0	Ending address bank 4	0x00	Ending address for bank 4	

Figure 4-13, Figure 4-14, and Table 4-23 depict the extended memory ending address register 1 and 2 bit settings.

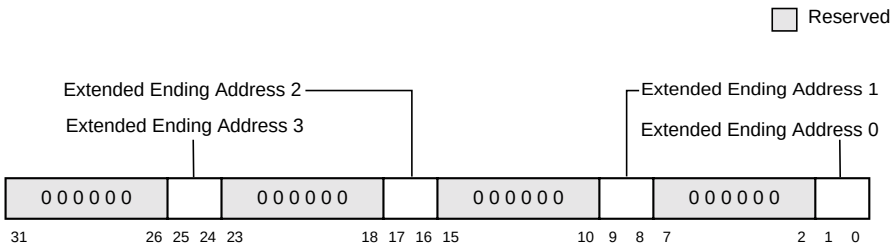

Figure 4-13. Extended Memory Ending Address Register 1—0x98

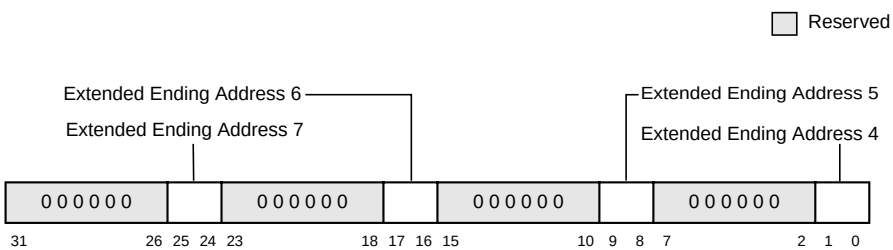

Figure 4-14. Extended Memory Ending Address Register 2—0x9C

Table 4-23. Bit Settings for Extended Memory Ending Address Registers 1 and 2

Bits	Name	Reset Value	Description	Byte Address
31–26	—	All 0s	Reserved	0x98
25–24	Extended ending address 3	0b00	Extended ending address for bank 3	
23–18	—	All 0s	Reserved	
17–16	Extended ending address 2	0b00	Extended ending address for bank 2	
15–10	—	All 0s	Reserved	
9–8	Extended ending address 1	0b00	Extended ending address for bank 1	
7–2	—	All 0s	Reserved	
1–0	Extended ending address 0	0b00	Extended ending address for bank 0	

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Table 4-23. Bit Settings for Extended Memory Ending Address Registers 1 and 2

Bits	Name	Reset Value	Description	Byte Address
31–26	—	All 0s	Reserved	0x9C
25–24	Extended ending address 7	0b00	Extended ending address for bank 7	
23–18	—	All 0s	Reserved	
17–16	Extended ending address 6	0b00	Extended ending address for bank 6	
15–10	—	All 0s	Reserved	
9–8	Extended ending address 5	0b00	Extended ending address for bank 5	
7–2	—	All 0s	Reserved	
1–0	Extended ending address 4	0b00	Extended ending address for bank 4	

4.6.2 Memory Bank Enable Register—0xA0

Individual banks of memory are enabled or disabled by using the 1-byte memory bank enable register, shown in Figure 4-15 and Table 4-24. Each enabled memory bank corresponds to a physical bank of memory enabled by one of the $\overline{RAS}$[0:7] signals (for DRAM/EDO) or one of the $\overline{CS}$[0:7] signals (for SDRAM). If a bank is enabled, the ending address of that bank must be greater than or equal to its starting address. If a bank is disabled, no memory transactions access that bank regardless of its starting and ending addresses.

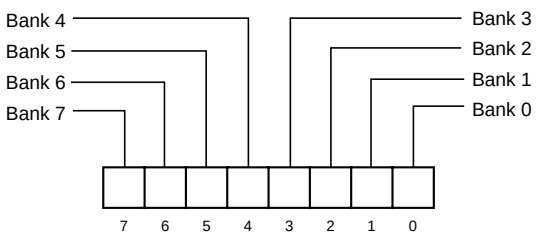

Figure 4-15. Memory Bank Enable Register—0xA0

Table 4-24. Bit Settings for Memory Bank Enable Register—0xA0

Bits	Name	Reset Value	Description
7	Bank 7	0	Bank 7 0 Disabled 1 Enabled
6	Bank 6	0	Bank 6 0 Disabled 1 Enabled

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Table 4-24. Bit Settings for Memory Bank Enable Register—0xA0 (Continued)

Bits	Name	Reset Value	Description
5	Bank 5	0	Bank 5 0 Disabled 1 Enabled
4	Bank 4	0	Bank 4 0 Disabled 1 Enabled
3	Bank 3	0	Bank 3 0 Disabled 1 Enabled
2	Bank 2	0	Bank 2 0 Disabled 1 Enabled
1	Bank 1	0	Bank 1 0 Disabled 1 Enabled
0	Bank 0	0	Bank 0 0 Disabled 1 Enabled

4.6.3 Memory Page Mode Register—0xA3

The 1-byte memory page mode register, shown in Figure 4-16 and Table 4-25, contains the PGMAX parameter which controls how long the MPC8240 retains the currently accessed page (row) in memory. See Section 6.3.7, “FPM or EDO DRAM Page Mode Retention,” or Section 6.2.7, “SDRAM Page Mode,” for more information.

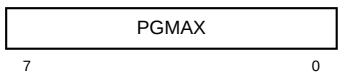

Figure 4-16. Memory Page Mode Register—0xA3

Table 4-25. Bit Settings for Memory Page Mode Register—0xA3

Bits	Name	Reset Value	Description
7–0	PGMAX	All 0s	For DRAM/EDO configurations, the value of PGMAX multiplied by 64 determines the maximum $\overline{RAS}$ assertion interval for retained page mode. When programmed to 0x00, page mode is disabled. For SDRAM configurations, the value of PGMAX multiplied by 64 determines the activate to precharge interval (sometimes called row active time or t_{RAS}) for retained page mode. When programmed to 0x00, page mode is disabled.

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4.7 Processor Interface Configuration Registers

The processor interface configuration registers (PICRs) control the programmable parameters of the peripheral bus interface to the processor core. There are two 32-bit PICRs—PICR1 and PICR2. Figure 4-17 shows the bits of PICR1.

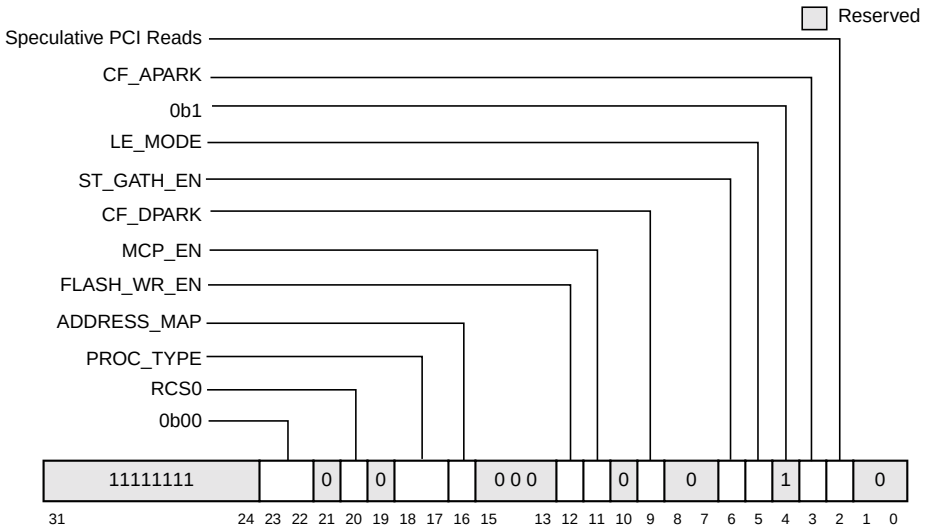

Figure 4-17. Processor Interface Configuration Register 1 (PICR1)—0xA8

Table 4-26 describes the PICR1 bit settings.

Table 4-26. Bit Settings for PICR1—0xA8

Bits	Name	Reset Value	Description
31–24 addr<ab>	—	All 1s	Reserved
23–22 addr<aa>	—	00	00 Must be cleared to 0b00
21	—	0	Reserved
20	RCS0	x	ROM location (read only.) This bit indicates the state of the ROM location ($\overline{\text{RCS0}}$) configuration signal during reset. 0 ROM is located on PCI bus. 1 ROM is located on processor/memory data bus.
19	—	0	Reserved

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Table 4-26. Bit Settings for PICR1—0xA8 (Continued)

Bits	Name	Reset Value	Description
18–17	PROC_TYPE	10	Processor type. These bits identify the type of processor used in the system and determine the $\overline{QREQ}$, $\overline{QACK}$ protocol used for power management. 10 603e
16	ADDRESS_MAP	x	Address map. This bit controls which address map is used by the MPC8240. The initial state of this bit is determined by the inverse of the address map configuration signal (MAA0) during reset.Software that dynamically changes this bit must ensure that there are no pending PCI transactions and that there is a **sync** instruction following the address map change to allow the update to take effect. See Chapter 3, “Address Maps,” for more information. 0 The MPC8240 is configured for address map B. 1 The MPC8240 is configured for address map A (not supported when operating in PCI agent mode).
15–13 addr <a9>	—	00	Reserved
12	FLASH_WR_EN	0	Flash write enable. This bit controls whether the MPC8240 allows write operations to Flash ROM. Note that if writes to Flash are enabled (with read-only devices in the banks), and a write transaction occurs, then bus contention may occur because the write data is driven on the data bus, and the read-only device starts driving the data bus. This can be avoided by disabling write capability to the Flash/ROM address space through the FLASH_WR_EN and/or FLASH_WR_LOCKOUT_EN configuration bits or by connecting the $\overline{FOE}$ signal to the output enable of the read-only device. 0 Flash write is disabled. 1 Flash write is enabled.
11	MCP_EN	0	Machine check enable. This bit controls whether the MPC8240 asserts $\overline{MCP}$ (and takes the machine check exception) upon detecting an error. See Chapter 13, “Error Handling,” for more information. 0 Machine check is disabled. 1 Machine check is enabled.
10	—	0	Reserved
9	CF_DPARK	0	Data bus park. This bit indicates whether the processor core is parked on the peripheral logic data bus. 0 Processor core is not parked on the data bus. 1 Processor core is parked on the data bus. It is recommended that software set this bit.
8–7	—	0	Reserved
6	ST_GATH_EN	0	This bit enables store gathering of writes from the processor to PCI memory space. See Chapter 12, “Central Control Unit,” for more information. 0 Store gathering is disabled. 1 Store gathering is enabled.

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Table 4-26. Bit Settings for PICR1—0xA8 (Continued)

Bits	Name	Reset Value	Description
5	LE_MODE	0	This bit controls the endian mode of the MPC8240. See Appendix B, “Bit and Byte Ordering,” for more information. 0 Big-endian mode 1 Little-endian mode
4	—	1	Reserved and must be set
3	CF_APARK	0	This bit indicates whether the processor address bus is parked. 0 Indicates that the processor core is not parked on the peripheral logic address bus 1 Indicates that the processor core is parked on the peripheral logic address bus
2	Speculative PCI Reads	0	This bit controls speculative PCI reads from memory. Note that the peripheral logic block performs a speculative read in response to a PCI read-multiple command, even if this bit is cleared. See Chapter 12, “Central Control Unit,” for more information. 0 Indicates that speculative reads are disabled. 1 Indicates that speculative reads are enabled.
1–0	—	00	Reserved

Figure 4-18 shows the bits of the PICR2.

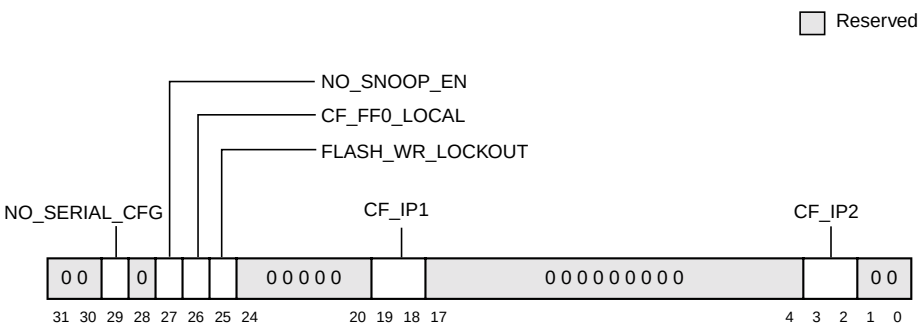

Figure 4-18. Processor Interface Configuration Register 2 (PICR2)—0xAC

Table 4-27 describes the bit settings for PICR2.

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Table 4-27. Bit Settings for PICR2—0xAC

Bits	Name	Reset Value	Description
31–30	—	00	Reserved
29	NO_SERIAL_CFG	0	This bit controls whether the MPC8240 serializes configuration writes to PCI devices from the processor. 0 Configuration writes to PCI devices from the processor cause the MPC8240 to serialize and flush the internal buffers. 1 Configuration writes to PCI devices from the processor do not cause serialization. The internal buffers are not flushed.
28	—	0	Reserved
27	NO_SNOOP_EN	0	This bit controls whether the MPC8240 generates snoop transactions on the peripheral logic bus for PCI-to-system memory transactions. This is provided as a performance enhancement for systems that do not need to maintain coherency on system memory accesses by PCI. 0 Snooping is enabled. 1 Snooping is disabled.
26	CF_FF0_LOCAL	0	ROM remapping enable. This bit allows the lower 8 Mbytes of the ROM/Flash address range to be remapped from the PCI bus to the processor/memory bus. Note that this bit is meaningful only if the ROM location parameter indicates that ROM is located on PCI bus (PICR1[RCS0] = 0). 0 ROM/Flash remapping disabled. The lower 8 Mbytes of the ROM/Flash address space are not remapped. All ROM/Flash accesses are directed to the PCI bus. 1 ROM/Flash remapping enabled. The lower 8 Mbytes of the ROM/Flash address space are remapped to the processor/memory bus. ROM/Flash accesses in the range 0xFF00_0000–0xFF7F_FFFF are directed to the processor/memory bus. ROM/Flash accesses in the range 0xFF80_0000–0xFFFF_FFFF are directed to the PCI bus.
25	FLASH_WR_LOCKOUT	0	Flash write lockout. This bit, once set, prevents writing to Flash. Once set, this bit can only be cleared by a hard reset. 0 Write operations to Flash are enabled, provided FLASH_WR_EN = 1. 1 Write operations to Flash are disabled until the MPC8240 is reset.
24–20	—	0_0000	Reserved
19–18	CF_IP1	11	Internal parameter 1. Should be programmed based on processor-to-memory clock ratios. 00 Use for all other processor-to-memory clock ratios. 01 Use for 1:1 or 3:2 processor-to-memory clock ratios. 10 Reserved; do not use. 11 Default; however, should be changed to 00 or 01.
17–4	—	All 0s	Reserved

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Table 4-27. Bit Settings for PICR2—0xAC (Continued)

Bits	Name	Reset Value	Description
3–2	CF_IP2	11	Internal parameter 2 00 Use for optimal performance. 01 Reserved; do not use. 10 Reserved; do not use. 11 Default; however should be changed to 0b00 for optimal performance.
1–0	—	00	Reserved

4.8 Error Handling Registers

Chapter 13, “Error Handling,” describes specific error conditions and how the MPC8240 responds to them. The registers at offsets 0xB8, 0xB9, and 0xC0 through 0xCB control the error handling and reporting for the MPC8240. The following sections provide descriptions of these registers.

4.8.1 ECC Single-Bit Error Registers

The ECC single-bit error registers are two 8-bit registers used to control the reporting of ECC single-bit errors. See Chapter 13, “Error Handling,” for more information. The ECC single-bit error counter, shown in Figure 4-19, maintains a count of the number of single-bit errors that have been detected. It is a read/write register that is cleared to 0x00 whenever any data is written to it.

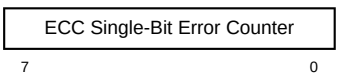

Figure 4-19. ECC Single-Bit Error Counter Register—0xB8

Table 4-28 describes the bits of the ECC single-bit error counter.

Table 4-28. Bit Settings for ECC Single-Bit Error Counter Register—0xB8

Bits	Name	Reset Value	Description
7–0	ECC single-bit error counter	All 0s	These bits maintain a count of the number of ECC single-bit errors that have been detected and corrected. If this value equals the value contained in the ECC single-bit error trigger register, then an error is reported (provided ErrEnR1[2] = 1).

The ECC single-bit error trigger, shown in Figure 4-20, provides a threshold value that, when equal to the single-bit error count, triggers the MPC8240 error reporting logic.

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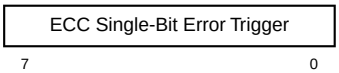

Figure 4-20. ECC Single-Bit Error Trigger Register—0xB9

Table 4-29 describes the bits of the ECC single-bit error trigger.

Table 4-29. Bit Settings for ECC Single-Bit Error Trigger Register—0xB9

Bits	Name	Reset Value	Description
7–0	ECC single-bit error trigger	All 0s	These bits provide the threshold value for the number of ECC single-bit errors that are detected before reporting an error condition. If the value of the single bit error counter register equals the value of this register, then an error is reported (provided ErrEnR1[2] = 1). If this register = 0x00, then no single bit error is ever generated.

4.8.2 Error Enabling and Detection Registers

The error enabling registers 1 and 2 (ErrEnR1 and ErrEnR2), shown in Figure and Figure 4-24, control whether the MPC8240 recognizes and reports specific error conditions. Table 4-30 describes the bits of ErrEnR1, and Table 4-33 describes the bits of ErrEnR2.

The error detection registers 1 and 2 (ErrDR1 and ErrDR2), shown in Figure 4-22 and Figure 4-25, contain error flags that report when the MPC8240 detects a specific error condition.

The error detection registers are bit-reset type registers. That is, reading from these registers occurs normally; however, write operations are different in that bits (error flags) can be cleared but not set. A bit is cleared whenever the register is written, and the data in the corresponding bit location is a 1. For example, to clear bit 6 and not affect other bits in the register, write 0b0100_0000 to the register. When the MPC8240 detects an error, the appropriate error flag is set. Subsequent errors set the appropriate error flags in the error detection registers, but the bus error status and error address are not recorded until the previous error flags are cleared.

The processor bus error status register (BESR) is also described in this section, as its address offset is 0xC3, which falls in between the ErrDR1 and ErrEnR2 in the memory map. This register saves the value of the TT[0:4] and TSIZ[0:2] when a processor-initiated bus error is detected.

Finally the PCI bus error status register and processor/PCI error address register are described at the end of this subsection.

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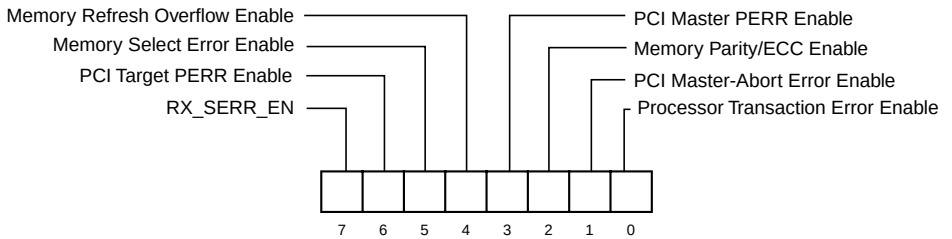
Memory Refresh Overflow Enable
Memory Select Error Enable
PCI Target PERR Enable
RX_SERR_EN
PCI Master PERR Enable
Memory Parity/ECC Enable
PCI Master-Abort Error Enable
Processor Transaction Error Enable
7 6 5 4 3 2 1 0

Figure 4-21. Error Enabling Register 1 (ErrEnR1)—0xC0

Table 4-30. Bit Settings for Error Enabling Register 1 (ErrEnR1)—0xC0

Bits	Name	Reset Value	Description
7	RX_SERR_EN	0	This bit enables the reporting of $\overline{\text{SERR}}$ assertions that occur on the PCI bus two clock cycles after the address phase of transactions where the MPC8240 is the initiator. 0 Received PCI $\overline{\text{SERR}}$ disabled 1 Received PCI $\overline{\text{SERR}}$ enabled
6	PCI target $\overline{\text{PERR}}$ enable	0	This bit enables the reporting of data parity errors on the PCI bus for transactions involving the MPC8240 as a target. 0 Target $\overline{\text{PERR}}$ disabled 1 Target $\overline{\text{PERR}}$ enabled
5	Memory select error enable	0	This bit enables the reporting of memory select errors that occur on (attempted) accesses to system memory. 0 Memory select error disabled 1 Memory select error enabled
4	Memory refresh overflow enable	0	This bit enables the reporting of memory refresh overflow errors. 0 Memory refresh overflow disabled 1 Memory refresh overflow enabled
3	PCI master $\overline{\text{PERR}}$ enable	0	This bit enables the reporting of data parity errors on the PCI bus for transactions involving the MPC8240 as a master. 0 Master $\overline{\text{PERR}}$ disabled 1 Master $\overline{\text{PERR}}$ enabled
2	Memory parity/ECC enable	0	This bit enables the reporting of system memory read parity errors that occur on accesses to system memory or those that exceed the ECC single-bit error threshold. [For SDRAM with in-line ECC/parity, this is the memory write parity enable bit.] 0 Memory read parity/ECC single-bit threshold disabled 1 Memory read parity/ECC single-bit threshold enabled

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Table 4-30. Bit Settings for Error Enabling Register 1 (ErrEnR1)—0xC0 (Continued)

Bits	Name	Reset Value	Description
1	PCI master-abort error enable	0	This bit enables the reporting of master-abort errors that occur on the PCI bus for transactions involving the MPC8240 as a master. 0 PCI master-abort error disabled 1 PCI master-abort error enabled
0	Processor transaction error enable	1	This bit enables the reporting of processor transaction errors. 0 Processor transaction error disabled 1 Processor transaction bus error enabled

Figure 4-22 shows the bits of error detection register 1.

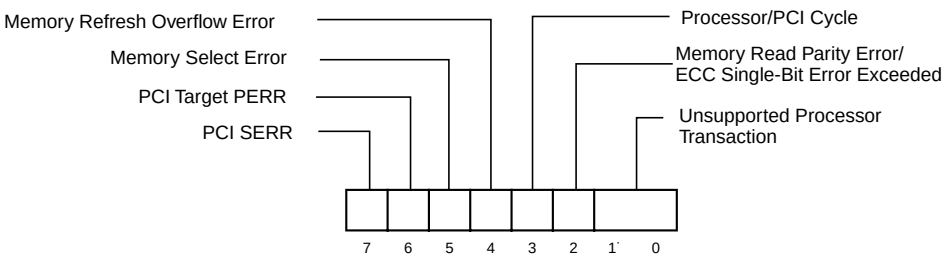

Figure 4-22. Error Detection Register 1 (ErrDR1)—0xC1

Table 4-31 describes the bits of error detection register 1.

Table 4-31. Bit Settings for Error Detection Register 1 (ErrDR1)—0xC1

Bits	Name	Reset Value	Description
7	PCI $\overline{\text{SERR}}$	0	MPC8240, as a PCI initiator, detected $\overline{\text{SERR}}$ asserted by an external PCI agent two clock cycles after the address phase. 0 $\overline{\text{SERR}}$ not detected 1 $\overline{\text{SERR}}$ detected
6	PCI target $\overline{\text{PERR}}$	0	PCI target $\overline{\text{PERR}}$ 0 The MPC8240, as a PCI target, has not detected a data parity error 1 The MPC8240, as a PCI target, detected a data parity error
5	Memory select error	0	Memory select error 0 No error detected 1 Memory select error detected
4	Memory refresh overflow error	0	Memory refresh overflow error 0 No error detected 1 Memory refresh overflow has occurred
3	Processor/PCI cycle	0	Processor/PCI cycle 0 Error occurred on a processor-initiated cycle. 1 Error occurred on a PCI-initiated cycle.

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Table 4-31. Bit Settings for Error Detection Register 1 (ErrDR1)—0xC1 (Continued)

Bits	Name	Reset Value	Description
2	Memory read parity error/ECC single-bit error trigger exceeded	0	Memory read parity error/ECC single-bit error trigger exceeded 0 No error detected 1 Parity error detected or ECC single-bit error trigger exceeded
1–0	Unsupported processor transaction	00	Unsupported processor transaction 00 No error detected 01 Unsupported transfer attributes. Refer to Chapter 13, “Error Handling,” for more details. 10 Reserved 11 Reserved

The processor bus error status register (BESR) latches the state of the internal processor address attributes when an internal bus error is detected. This information then can be used by error handling software. Figure 4-23 shows the bits of the processor bus error status register and Table 4-32 provides a detailed description of the bit settings.

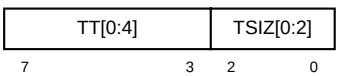

Figure 4-23. Internal Processor Bus Error Status Register—0xC3

Table 4-32. Bit Settings for Internal Processor Bus Error Status Register—0xC3

Bits	Name	Reset Value	Description
7–3	TT[0:4]	0000_0	These bits maintain a copy of TT[0:4]. When a processor bus error is detected, these bits are latched until all error flags are cleared.
2–0	TSIZ[0:2]	000	These bits maintain a copy of TSIZ[0:2]. When a processor bus error is detected, these bits are latched until all error flags are cleared.

Figure 4-24 shows the enable bits for ErrEnR2.

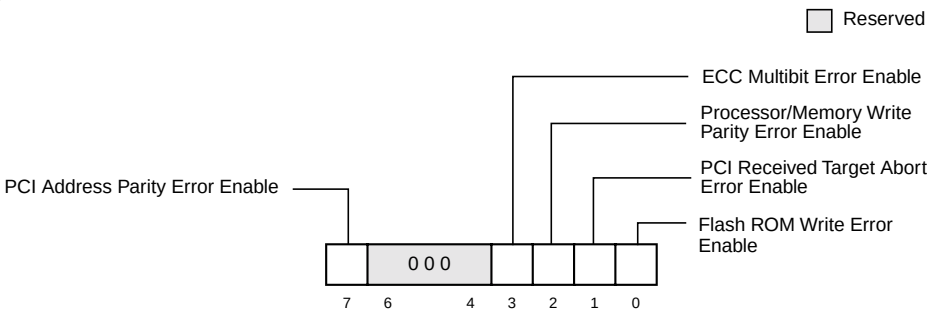

Figure 4-24. Error Enabling Register 2 (ErrEnR2)—0xC4

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Table 4-33 describes the bits for ErrEnR2.

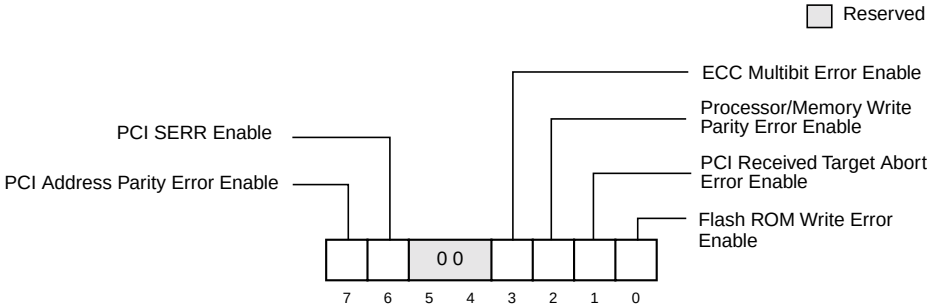
Reserved
ECC Multibit Error Enable
Processor/Memory Write Parity Error Enable
PCI SERR Enable
PCI Received Target Abort Error Enable
PCI Address Parity Error Enable
Flash ROM Write Error Enable
0 0
7 6 5 4 3 2 1 0

Table 4-33. Bit Settings for Error Enabling Register 2 (ErrEnR2)—0xC4

Bits	Name	Reset Value	Description
7	PCI address parity error enable	0	This bit controls whether the MPC8240 asserts $\overline{\text{MCP}}$ (provided $\overline{\text{MCP}}$ is enabled) if an address parity error is detected by the MPC8240 acting as a PCI target. 0 PCI address parity errors disabled 1 PCI address parity errors enabled
6–4	—	000	Reserved
3	ECC multi-bit error enable	0	This bit enables the detection of ECC multibit errors. 0 ECC multi-bit error detection disabled 1 ECC multi-bit error detection enabled
2	Processor memory write parity error enable	0	This bit enables the detection of processor memory write parity errors. (note: applies only for SDRAM with in-line parity checking). 0 Processor memory write error detection disabled 1 Processor memory write error detection enabled
1	PCI received target abort error enable	0	This bit enables the detection of target abort errors received by the PCI interface. 0 Target abort error detection disabled 1 Target abort error detection enabled
0	Flash ROM write error enable	0	This bit controls whether the MPC8240 detects attempts to write to Flash when either PICR1[FLASH_WR_EN] = 0 or PICR2[FLASH_WR_LOCKOUT] = 0. 0 Disabled 1 Enabled

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Figure 4-25 shows the bits for error detection register 2.

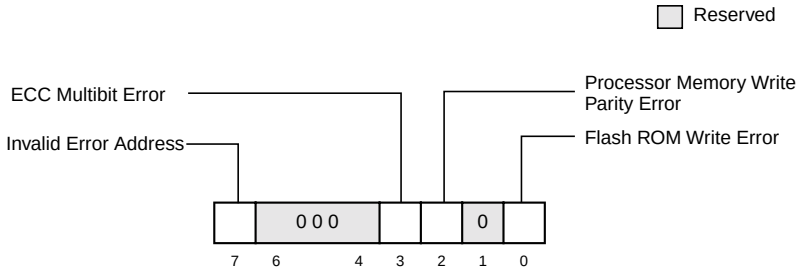

Figure 4-25. Error Detection Register 2 (ErrDR2)—0xC5

Table 4-34 describes the bits of error detection register 2.

Table 4-34. Bit Settings for Error Detection Register 2 (ErrDR2)—0xC5

Bits	Name	Reset Value	Description
7	Invalid error address	0	This bit indicates whether the address stored in the processor/PCI error address register is valid. 0 The address in the error address register is valid. 1 The address in the error address register is not valid.
6–4	—	000	Reserved
3	ECC multi bit error	0	ECC multibit error 0 No ECC multi bit error detected 1 ECC multibit error detected
2	Processor memory write parity error	0	Processor memory write parity error (SDRAM with in-line parity checking only). 0 No error detected 1 Processor memory write parity error detected
1	—	0	Reserved
0	Flash ROM write error	0	Flash ROM write error 0 No error detected 1 The MPC8240 detected a write to Flash ROM when writes to ROM/Flash are disabled.

The PCI bus error status register latches the state of the PCI $\overline{\text{C/BE}}$[3:0] signals when an error is detected on the PCI bus as defined in Section 13.3.3, “PCI Interface Errors.”

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Figure 4-26 shows the PCI bus error status register.

Figure 4-26. PCI Bus Error Status Register—0xC7

Table 4-35 describes the bits of the PCI bus error status register.

Table 4-35. Bit Settings for PCI Bus Error Status Register—0xC7

Bits	Name	Reset Value	Description
7–5	—	000	Reserved
4	MPC8240 master/target status	0	MPC8240 master/target status 0 MPC8240 is the PCI master. 1 MPC8240 is the PCI target.
3–0	C/BE[3:0]	0000	These bits maintain a copy of C/BE[3:0]. When a PCI bus error is detected, these bits are latched until all error flags are cleared.

The processor/PCI error address register maintains address bits for either the processor bus or the PCI bus transaction that generated an error as shown in Figure 4-27.

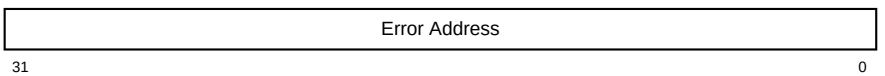

Figure 4-27. Processor/PCI Error Address Register—0xC8

Table 4-36 describes the bits of processor/PCI error address register.

Table 4-36. Bit Settings for Processor/PCI Error Address Register—0xC8

Bits	Name	Reset Value	Description
31–24	Error address	0x00	A[24:31] or AD[7:0]—Dependent on whether the error is a processor bus error or a PCI bus error. When an error is detected, these bits are latched until all error flags are cleared.
23–16		0x00	A[16:23] or AD[15:8]—(Dependent on whether the error is a processor bus error or a PCI bus error. When an error is detected, these bits are latched until all error flags are cleared.
15–8		0x00	A[8:15] or AD[23:16]—Dependent on whether the error is a processor bus error or a PCI bus error. When an error is detected, these bits are latched until all error flags are cleared.
7–0		0x00	A[0:7] or AD[31:24]—Dependent on whether the error is a processor bus error or a PCI bus error. When an error is detected, these bits are latched until all error flags are cleared.

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4.9 Address Map B Options Register—0xE0

The address map B options register (AMBOR) controls various configuration settings that can be used to alias some addresses and to control accesses to holes in the address map. Unrelated to address map B, there is also a bit that controls the operation of the DLL. See Section 3.3.2, “DLL Operation and Locking,” for more information about operation of the DLL.

Figure 4-28 shows the bits of the AMBOR.

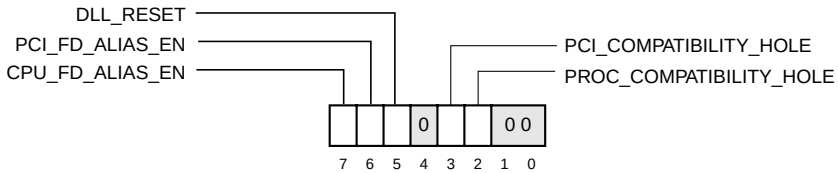

Figure 4-28. Address Map B Options Register (AMBOR)—0xE0

Table 4-37 shows the specific bit settings for the AMBOR.

Table 4-37. Bit Settings for the AMBOR—0xE0

Bits	Name	Reset Value	Description
7	CPU_FD_ALIAS_EN	1	Used to direct processor accesses to addresses that begin with 0xFDxx_xxxx. This bit is used only for address map B (and not supported in agent mode). 0 Access are routed normally 1 Processor accesses with 0xFDxx_xxxx address are forwarded to the PCI bus as PCI memory accesses to 0x00xx_xxxx.
6	PCI_FD_ALIAS_EN	1	Used to direct processor responses to addresses that begin with 0xFDxx_xxxx. This bit is used only for address map B (and not supported in agent mode). 0 No response 1 The MPC8240, as a PCI target, responds to addresses in the range 0xFD00_0000–0xFDFF_FFFF (asserts $\overline{\text{DEVSEL}}$), and forwards the transaction to system memory as 0x0000_0000–0x00FF_FFFF.
5	DLL_RESET	0	Used to reset the DLL tap point. See Section 3.3.2, “DLL Operation and Locking.” This bit must be explicitly set and then cleared by software during initialization in order to guarantee correct operation of the DLL and the SDRAM_CLK[0:3] signals (if they are used) 0 DLL tries to lock the phase between the SDRAM_SYNC_IN signal and the internal sys_logic_clk signal. 1 The SDRAM_CLK signals are driven from tap point 0 of the internal delay line.
4	—	0	Reserved

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Table 4-37. Bit Settings for the AMBOR—0xE0 (Continued)

Bits	Name	Reset Value	Description
3	PCI_COMPATIBILITY_ HOLE	0	This bit is used only for address map B (not supported in agent mode). 0 The MPC8240, as a PCI target, responds to PCI addresses in the range 0x000A_0000–0x000F_FFFF and forwards the transaction to system memory. 1 The MPC8240, as a PCI target, does not respond to PCI addresses in the range 0x000A_0000–0x000F_FFFF.
2	PROC_COMPATIBILITY_ HOLE	0	This bit is used only for address map B (not supported in agent mode). 0 The MPC8240 forwards processor-initiated transactions in the address range 0x000A_0000–0x000B_FFFF to system memory. 1 The MPC8240 forwards processor-initiated transactions in the address range 0x000A_0000–0x000B_FFFF to the PCI memory space.
1–0	—	00	Reserved

4.10 Memory Control Configuration Registers

The four 32-bit memory control configuration registers (MCCRs) set all RAM and ROM parameters. These registers are programmed by initialization software to adapt the MPC8240 to the specific memory organization used in the system. After all the memory configuration parameters have been properly configured, the initialization software turns on the memory interface using the MEMGO bit in MCCR1.

Note that the RAM_TYPE bit in MCCR1 must be cleared (to select SDRAM mode) before either the REGISTERED or buffer mode bits in MCCR4 are set to one. In-line or registered buffer modes are not supported in FPM/EDO DRAM systems and attempts to configure them may result in data corruption. This restriction includes the time between system reset and the setting of the MEMGO bit; therefore, it may dictate the order in which the memory controller configuration registers are written. It is recommended that the user first write MCCR1, 2, 3, and 4, in order, without setting the MEMGO bit. Afterwards, the user should perform a read-modify-write operation to set the MEMGO bit in MCCR1.

Figure 4-29 and Table 4-38 show the memory control configuration register 1 (MCCR1) format and bit settings.

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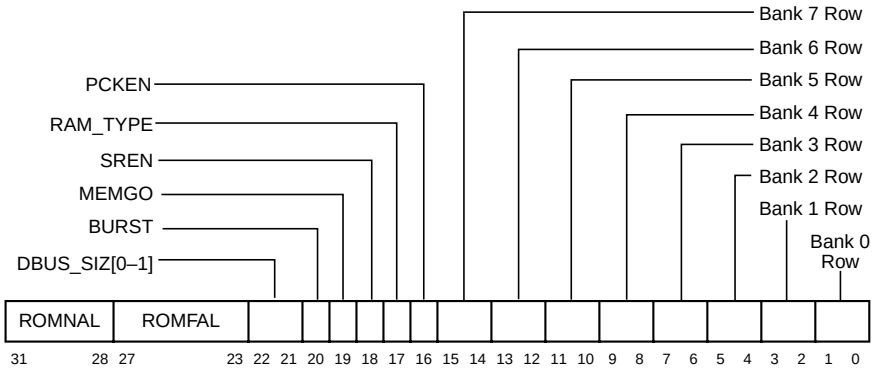

Figure 4-29. Memory Control Configuration Register 1 (MCCR1)—0xF0

Table 4-38. Bit Settings for MCCR1—0xF0

Bits	Name	Reset Value	Description
31–28	ROMNAL	All 1s	For burst-mode ROM and Flash reads, ROMNAL controls the next access time. The maximum value is 0b1111 (15). The actual cycle count is three cycles more than the binary value of ROMNAL. For Flash writes, ROMNAL measures the write pulse recovery (high) time. The maximum value is 0b1111 (15). The actual cycle count is four cycles more than the binary value of ROMNAL.
27–23	ROMFAL	All 1s	For nonburst ROM and Flash reads, ROMFAL controls the access time. For burst-mode ROMs, ROMFAL controls the first access time. The maximum value is 0b11111 (31). For the 64-bit and 32-bit configurations, the actual cycle count is three cycles more than the binary value of ROMFAL. For the 8-bit configuration, the actual cycle count is two cycles more than the binary value of ROMFAL. For Flash writes, ROMFAL measures the write pulse low time. The maximum value is 0b11111 (31). The actual cycle count is two cycles more than the binary value of ROMFAL.
22–21	DBUS_SIZ[0–1]	xx	Read-only. This field indicates the state of the ROM bank 0 data path width configuration signals [DL[0], $\overline{FOE}$] at reset as follows. For ROM/Flash chip select #0 ($\overline{RCS0}$), 00 32-bit data bus. x1 8-bit data bus. 10 64-bit data bus. For ROM/Flash chip select #1 ($\overline{RCS1}$) and (S)DRAM, 0x 32-bit data bus. For FPM/EDO systems only, (RAM_TYPE=1). 1x 64-bit data bus.

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Table 4-38. Bit Settings for MCCR1—0xF0 (Continued)

Bits	Name	Reset Value	Description
20	BURST	0	Burst mode ROM timing enable 0 Indicates standard (nonburst) ROM access timing 1 Indicates burst-mode ROM access timing
19	MEMGO	0	RAM interface logic enable. Note that this bit must not be set until all other memory configuration parameters have been appropriately configured by boot code. 0 MPC8240 RAM interface logic disabled 1 MPC8240 RAM interface logic enabled
18	SREN	0	Self-refresh enable. Note that if self refresh is disabled, the system is responsible for preserving the integrity of DRAM/EDO/SDRAM during sleep mode. 0 Disables the DRAM/EDO/SDRAM self refresh during sleep mode 1 Enables the DRAM/EDO/SDRAM self refresh during sleep mode
17	RAM_TYPE	1	RAM type 0 Indicates synchronous DRAM (SDRAM) 1 Indicates DRAM or EDO DRAM (depending on the setting for MCCR2[EDO]) Note that this bit must be cleared (selecting DRAM or SDRAM) before the in-line or registered buffer mode bits in MCCR4 are set.
16	PCKEN	0	Memory interface parity checking/generation enable 0 Disables parity checking and parity generation for transactions to DRAM/EDO/SDRAM memory. Note that this bit must be cleared for SDRAM memory when operating in in-line buffer mode (MCCR4[BUF_TYPE[0–1]] = 0b10) and in-line parity/ECC is enabled with MCCR2[INLINE_RD_EN] = 1. 1 Enables parity checking and generation for all registered or flow-through mode memory transactions to DRAM/EDO/SDRAM memory.
15–14	Bank 7 row	00	RAM bank 7 row address bit count. These bits indicate the number of row address bits that are required by the RAM devices in bank 7. For FPM/EDO DRAM configurations (RAM_TYPE = 1), the encoding is as follows: 00 9 row bits 01 10 row bits 10 11 row bits 11 12 or 13 row bits For SDRAM configurations (RAM_TYPE = 0), the encoding is as follows: 00 12 row bits by n column bits by 4 logical banks (12 × n × 4) or 11 row bits by n column bits by 4 logical banks (11 × n × 4) 01 13 row bits by n column bits by 2 logical banks (13 × n × 2) or 12 row bits by n column bits by 2 logical banks (12 × n × 2) 10 Reserved1111 row bits by n column bits by 2 logical banks (11 × n × 2)
13–12	Bank 6 row	00	RAM bank 6 row address bit count. See the description for Bank 7 row (bits 15–14).
11–10	Bank 5 row	00	RAM bank 5 row address bit count. See the description for Bank 7 row (bits 15–14).

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Table 4-38. Bit Settings for MCCR1—0xF0 (Continued)

Bits	Name	Reset Value	Description
9–8	Bank 4 row	00	RAM bank 4 row address bit count. See the description for Bank 7 row (bits 15–14).
7–6	Bank 3 row	00	RAM bank 3 row address bit count. See the description for Bank 7 row (bits 15–14).
5–4	Bank 2 row	00	RAM bank 2 row address bit count. See the description for Bank 7 row (bits 15–14).
3–2	Bank 1 row	00	RAM bank 1 row address bit count.See the description for Bank 7 row (bits 15–14).
1–0	Bank 0 row	00	RAM bank 0 row address bit count. See the description for Bank 7 row (bits 15–14).

Figure 4-30 and Table 4-39 show the memory control configuration register 2 (MCCR2) format and bit settings.

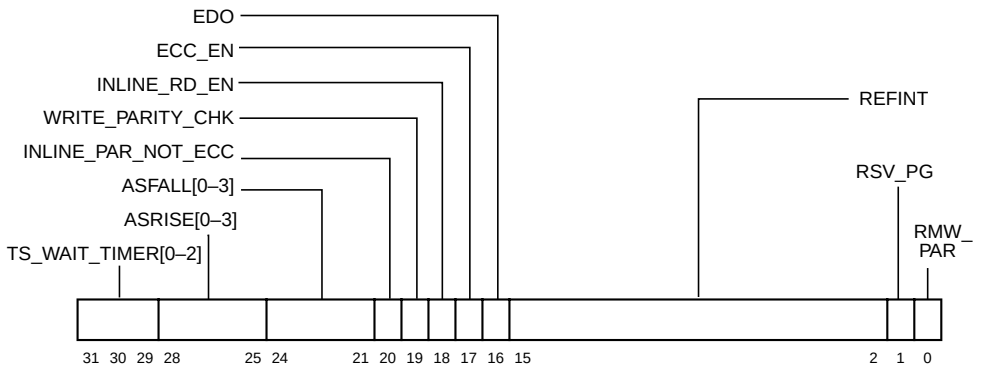

Figure 4-30. Memory Control Configuration Register 2 (MCCR2)—0xF4

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Table 4-39. Bit Settings for MCCR2—0xF4

<table>
<tr><th>Bits</th><th>Name</th><th>Reset Value</th><th>Description</th></tr>
<tr><td>31–29</td><td>TS_WAIT_ TIMER[0–2]</td><td>000</td><td>Transaction start wait states timer. The minimum time allowed for ROM/Flash/Port X devices to enter high impedance is 2 memory system clocks.
TS_WAIT_TIMER[0–2] adds wait states before the subsequent transaction starts in order to account for longer disable times of a ROM/Flash/Port X device. This delay is enforced after all ROM and Flash accesses, delaying the next memory access from starting (for example, DRAM after ROM access, SDRAM after Flash access, ROM after Flash access).
Note that this parameter is supported for SDRAM systems only. For EDO/FPM DRAM systems, TS_WAIT_TIMER[0–2] must = 000.
<table>
<tr><th rowspan="2">Bits</th><th colspan="3">Wait States for ROM High Impedance</th></tr>
<tr><th>Reads with wide data path (32 or 64-bit)</th><th>Reads with gather data path in flow-through or registered buffer mode (8, 16, 32-bit)</th><th>All writes[1, 2] and reads with gather data path in in-line buffer mode (8, 16, 32,-bit)</th></tr>
<tr><td>000</td><td>2 clocks</td><td>5 clocks</td><td>6 clocks</td></tr>
<tr><td>001</td><td>2 clocks</td><td>5 clocks</td><td>6 clocks</td></tr>
<tr><td>010</td><td>3 clocks</td><td>5 clocks</td><td>6 clocks</td></tr>
<tr><td>100</td><td>5 clocks</td><td>6 clocks</td><td>7 clocks</td></tr>
<tr><td>101</td><td>6 clocks</td><td>7 clocks</td><td>8 clocks</td></tr>
<tr><td>111</td><td>8 clocks</td><td>9 clocks</td><td>10 clocks</td></tr>
</table>
Note 1. In this context, Flash writes are defined as any write to $\overline{\text{RCS0}}$ or $\overline{\text{RCS1}}$.
Note 2: For Flash writes, add the write recovery time, ROMNAL, to the given wait states for ROM high-impedance time.</td></tr>
<tr><td>28–25</td><td>ASRISE[0–3]</td><td>0000</td><td>$\overline{\text{AS}}$ rise time. These bits control the rising edge timing of the $\overline{\text{AS}}$ signal for the Port X interface. See Section 6.4.7, “Port X Interface,” for more information.
0000 Disables $\overline{\text{AS}}$ signal generation
0001 1 clock
0010 2 clocks
0011 3 clocks
...
1111 15 clocks</td></tr>
<tr><td>24–21</td><td>ASFALL[0–3]</td><td>0000</td><td>$\overline{\text{AS}}$ fall time. These bits control the falling edge timing of the $\overline{\text{AS}}$ signal for the Port X interface. See Section 6.4.7, “Port X Interface,” for more information.
0000 0 clocks ($\overline{\text{AS}}$ asserted coincident with the chip select)
0001 1 clock
0010 2 clocks
0011 3 clocks
...
1111 15 clocks</td></tr>
</table>

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Table 4-39. Bit Settings for MCCR2—0xF4 (Continued)

Bits	Name	Reset Value	Description
20	INLINE_PAR_ NOT_ECC	0	In-line parity —not ECC. This bit selects between the ECC and parity checking/correction mechanisms of the in-line data path when performing memory reads. This bit is applicable for SDRAM systems running in in-line buffer mode (MCCR4[BUF_TYPE[0–1]] = 0b10) only, and when INLINE_RD_EN = 1. 0 MPC8240 uses ECC on the memory data bus. 1 MPC8240 uses parity on the memory data bus.
19	WRITE_ PARITY_ CHK	0	Write parity check enable. This bit controls whether the MPC8240 uses the parity checking hardware in the data path to report peripheral bus parity errors on memory system write operations. Write parity checking can be enabled for SDRAM, FPM, or EDO systems running in any buffer mode. This bit activates different parity checking hardware than that controlled by PCKEN. 0 peripheral bus write parity error reporting disabled 1 peripheral bus write parity error reporting enabled
18	INLINE_RD_ EN	0	In-line read parity or ECC check/correction enable. This bit controls whether the MPC8240 uses the ECC/parity checking and/or correction hardware in the in-line data path to report ECC or parity errors on memory system read operations. This bit activates different parity/ECC checking/correction hardware than that controlled by ECC_EN and PCKEN. Read parity/ECC checking can be enabled for SDRAM systems running in in-line buffer mode (MCCR4[BUF_TYPE[0–1]] = 0b10) only. Also, note that the INLINE_PAR_NOT_ECC bit selects between parity or ECC on the memory data bus when this bit is set. 0 In-line memory bus read parity/ECC error reporting disabled 1 In-line memory bus read parity/ECC error reporting enabled. Note that MCCR1[PCKEN] must be cleared when this bit is set.
17	ECC_EN	0	ECC enable. This bit controls whether the MPC8240 uses ECC for transactions to system memory. ECC_EN should be set only for systems using FPM/EDO memory. Note that the ECC_EN parameter overrides the PCKEN parameter. Also note that this bit and RMW_PAR cannot both be set, and it is illegal to set this bit with EDO = 1 and REGISTERED = 1. Systems using SDRAM use a different (in-line) ECC hardware and therefore, must have ECC_EN = 0. See Section 6.2, “SDRAM Interface Operation,” for more information. When ECC_EN = 1, the processor should not be configured to check address or data parity in the HID0 register. (See Section 5.3.1.2.1, “Hardware Implementation-Dependent Register 0 (HID0).” 0 ECC disabled 1 ECC enabled
16	EDO	0	EDO enable. This bit indicates the type of DRAMs for the MPC8240 memory interface. See Section 6.3, “FPM or EDO DRAM Interface Operation,” for more information. 0 Indicates standard DRAMs 1 Indicates EDO DRAMs

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Table 4-39. Bit Settings for MCCR2—0xF4 (Continued)

Bits	Name	Reset Value	Description
15–2	REFINT	All 0s	Refresh interval. These bits directly represent the number of clock cycles between CBR refresh cycles. One row is refreshed in each RAM bank during each CBR refresh cycle. The value for REFINT depends on the specific RAMs used and the operating frequency of the MPC8240. See Section 6.3.10, “FPM or EDO DRAM Refresh,” or Section 6.2.12, “SDRAM Refresh,” for more information. Note that the period of the refresh interval must be greater than the read/write access time to ensure that read/write operations complete successfully.
1	RSV_PG	0	Reserve page register. If this bit is set, the MPC8240 reserves one of the four page registers at all times. This is equivalent to only allowing three simultaneous open pages. 0 Four open page mode (default) 1 Reserve one of the four page registers at all times
0	RMW_PAR	0	Read-modify-write (RMW) parity enable. This bit controls how the MPC8240 writes parity bits to DRAM/EDO/SDRAM. Note that this bit does not enable parity checking and generation. PCKEN must be set to enable parity checking. Also note that this bit and ECC_EN cannot both be set to 1. See Section 6.3.8, “FPM or EDO DRAM Parity and RMW Parity,” and Section 6.2.9, “SDRAM Parity and RMW Parity,” for more information. 0 RMW parity disabled 1 RMW parity enabled. Note that this bit must be set for SDRAM systems that use in-line ECC (MCCR2[ECC_EN] = 0, MCCR4[BUF_TYPE[0–1]] = 0b10, and MCCR2[INLINE_PAR_NOT_ECC]] = 0).

Figure 4-31 and Table 4-40 show memory control configuration register 3 (MCCR3) format and bit settings.

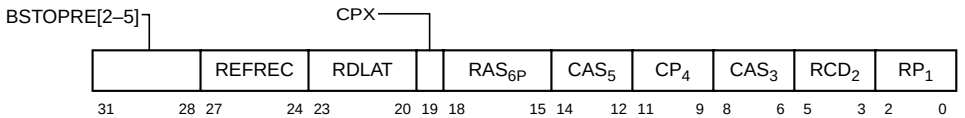

Figure 4-31. Memory Control Configuration Register 3 (MCCR3)—0xF8

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Table 4-40. Bit Settings for MCCR3—0xF8

Bits	Name	Reset Value	Description
31–28	BSTOPRE[2–5]	0000	Burst to precharge—bits 2–5. For SDRAM only. These bits, together with BSTOPRE[0–1] (bits 19–18 of MCCR4), and BSTOPRE[6–9] (bits 3–0 of MCCR4), control the open page interval. The page open duration counter is reloaded with BSTOPRE[0–9] every time the page is accessed (including page hits). When the counter expires, the open page is closed with a SDRAM-precharge bank command. Section 6.2.7, “SDRAM Page Mode,” for more information.
27–24	REFREC	0000	Refresh to activate interval. For SDRAM only. These bits control the number of clock cycles from an SDRAM-refresh command until an SDRAM-activate command is allowed. See Section 6.2.12, “SDRAM Refresh,” for more information. 0001 1 clock 0010 2 clocks 0011 3 clocks ... ... 1111 15 clocks 0000 16 clocks
23–20	RDLAT	0000	Data latency from read command. For SDRAM only. These bits control the number of clock cycles from an SDRAM-read command until the first data beat is available on the data bus. RDLAT values greater than 6 clocks are not supported. See Section 6.2.4, “SDRAM Power-On Initialization,” for more information. Note that for SDRAM, this value must be programmed to a valid value (from the reset value). 0000 Reserved 0001 1 clock 0010 2 clocks 0011 3 clocks 0100 4 clocks 0101 5 clocks 0110 6 clocks 0111 Reserved (not supported) ... ... 1111 Reserved (not supported)
19	CPX	0	$\overline{CAS}$ write timing modifier. For DRAM/EDO only. When set, this bit adds one clock cycle to the $\overline{CAS}$ precharge interval (CP_4 + 1) and subtracts one clock cycle from the $\overline{CAS}$ assertion interval for page mode access (CAS_5 - 1) for write operations to DRAM/EDO. Note that this requires $CAS_5 \geq 2$. Read operations are unmodified. See Section 6.3.5, “FPM or EDO DRAM Interface Timing,” for more information. 0 $\overline{CAS}$ write timing is unmodified 1 $\overline{CAS}$ write timing is modified as described above

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Table 4-40. Bit Settings for MCCR3—0xF8 (Continued)

Bits	Name	Reset Value	Description
18–15	RAS_{6P}	0000	$\overline{RAS}$ assertion interval for CBR refresh. For DRAM/EDO only. These bits control the number of clock cycles $\overline{RAS}$ is held asserted during CBR refresh. The value for RAS_{6P} depends on the specific DRAMs used and the frequency of the memory interface. See Section 6.3.10, “FPM or EDO DRAM Refresh,” for more information. 0001 1 clock 0010 2 clocks 0011 3 clocks ... ... 1111 15 clocks 0000 16 clocks
14–12	CAS_5	000	$\overline{CAS}$ assertion interval for page mode access. For DRAM/EDO only. These bits control the number of clock cycles $\overline{CAS}$ is held asserted during page mode accesses. The value for CAS_5 depends on the specific DRAMs used and the frequency of the memory interface. Note that when ECC is enabled, CAS_5 + CP_4 must equal four clock cycles. See Section 6.3.5, “FPM or EDO DRAM Interface Timing,” for more information. 001 1 clock 010 2 clocks 011 3 clocks ... ... 111 7 clocks 000 8 clocks
11–9	CP_4	000	$\overline{CAS}$ precharge interval. For DRAM/EDO only. These bits control the number of clock cycles that $\overline{CAS}$ must be held negated in page mode (to allow for column precharge) before the next assertion of $\overline{CAS}$. Note that when ECC is enabled, CAS_5 + CP_4 must equal four clock cycles. See Section 6.3.5, “FPM or EDO DRAM Interface Timing,” for more information. 001 1 clock 010 2 clocks 011 reserved ... ... 111 Reserved 000 Reserved
8–6	CAS_3	000	$\overline{CAS}$ assertion interval for the first access. For DRAM/EDO only. These bits control the number of clock cycles $\overline{CAS}$ is held asserted during a single beat or during the first access in a burst. The value for CAS_3 depends on the specific DRAMs used and the frequency of the memory interface. See Section 6.3.5, “FPM or EDO DRAM Interface Timing,” for more information. 001 1 clock 010 2 clocks 011 3 clocks ... ... 111 7 clocks 000 8 clocks

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Table 4-40. Bit Settings for MCCR3—0xF8 (Continued)

Bits	Name	Reset Value	Description
5–3	RCD_2	000	$\overline{RAS}$ to $\overline{CAS}$ delay interval. For DRAM/EDO only. These bits control the number of clock cycles between the assertion of $\overline{RAS}$ and the first assertion of $\overline{CAS}$. The value for RCD_2 depends on the specific DRAMs used and the frequency of the memory interface. However, RCD_2 must be at least two clock cycles. See Section 6.3.5, “FPM or EDO DRAM Interface Timing,” for more information. 001 Reserved 010 2 clocks 011 3 clocks ... ... 111 7 clocks 000 8 clocks
2–0	RP_1	000	$\overline{RAS}$ precharge interval. For DRAM/EDO only. These bits control the number of clock cycles that $\overline{RAS}$ must be held negated (to allow for row precharge) before the next assertion of $\overline{RAS}$. Note that RP_1 must be at least two clock cycles and no greater than 5 clock cycles. See Section 6.3.5, “FPM or EDO DRAM Interface Timing,” for more information. 010 2 clocks 011 3 clocks 110 4 clocks 101 5 clocks All others: reserved

Figure 4-32 and Table 4-41 show memory control configuration register 4 (MCCR4) format and bit settings.

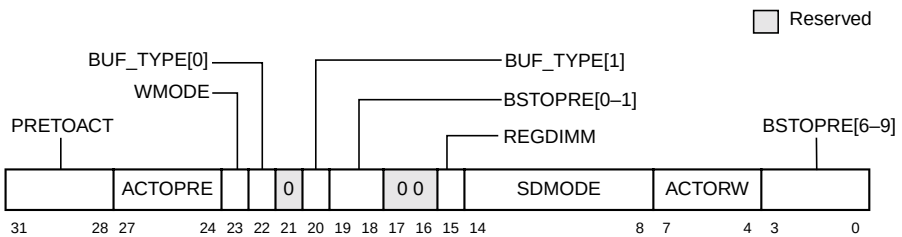

Figure 4-32. Memory Control Configuration Register 4 (MCCR4)—0xFC

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Table 4-41. Bit Settings for MCCR4—0xFC

Bits	Name	Reset Value	Description
31–28	PRETOACT	0000	Precharge to activate interval. For SDRAM only. These bits control the number of clock cycles from an SDRAM-precharge command until an SDRAM-activate command is allowed. See Section 6.2.4, “SDRAM Power-On Initialization,” for more information. 0001 1 clock 0010 2 clocks 0011 3 clocks ... ... 1111 15 clocks 0000 16 clocks
27–24	ACTOPRE	0000	Activate to precharge interval. For SDRAM only. These bits control the number of clock cycles from an SDRAM-activate command until an SDRAM-precharge command is allowed. See Section 6.2.4, “SDRAM Power-On Initialization,” for more information. 0001 1 clock 0010 2 clocks 0011 3 clocks ... ... 1111 15 clocks 0000 16 clocks
23	WMODE	0	Length of burst for 32-bit data. Applies to 32-bit data path mode only. Determines whether the burst ROMs can accept eight beats in a burst or only four. In 32-bit data path mode, burst transactions require data beats. If the burst ROM can only accept four beats per burst, the memory controller must perform two transactions to the ROM. 0 Four beats per burst (default) 1 Eight beats per burst
22	BUF_TYPE[0]	0	Most significant bit of the memory data bus buffer type field. BUF_TYPE[0] is used with bit 20 below (BUF_TYPE[1]) to configure the internal memory data path buffering scheme as follows: BUF_TYPE[0–1]: 00 Flow through buffer mode (default) 01 Registered buffer mode 10 In-line buffer mode; SDRAM only 11 Reserved The MPC8240 must be configured for in-line buffer mode in order to use the in-line ECC/parity logic for SDRAM. The in-line ECC and parity hardware allow the MPC8240 to check/generate parity on the internal peripheral logic bus and check/correct/generate ECC or parity on the external SDRAM memory bus. See Section 6.2.3, “SDRAM Memory Data Interface,” and Section 6.3.3, “FPM or EDO Memory Data Interface,” for more information.
21	—	0	Reserved

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Table 4-41. Bit Settings for MCCR4—0xFC (Continued)

Bits	Name	Reset Value	Description
20	BUF_TYPE[1]	0	Least significant bit of the memory data bus buffer type field. BUF_TYPE[1] is used with bit 22 above (BUF_TYPE[0]) to configure the internal memory data path buffering scheme as described for bit 22.
19–18	BSTOPRE[0–1]	00	Burst to precharge—bits 0–1. For SDRAM only. These bits, together with BSTOPRE[2–5] (bits 31–28 of MCCR3), and BSTOPRE[6–9] (bits 3–0 of MCCR4), control the open page interval. The page open duration counter is reloaded with BSTOPRE[0–9] every time the page is accessed (including page hits). When the counter expires, the open page is closed with a SDRAM-precharge bank command. See Chapter 6, “MPC8240 Memory Interface,” for more information.
17–16	—	00	Reserved
15	REGDIMM	0	Registered DIMMs. Memory data and parity data path buses configured for registered DIMMs. For SDRAM only. When enabled (REGDIMM = 1), SDRAM write data and parity are delayed by one cycle on the memory bus with respect to the SDRAM control signals (for example, $\overline{\text{SDRAS}}$, $\overline{\text{SDCAS}}$, $\overline{\text{WE}}$). 0 Normal DIMMs 1 Registered DIMMs selected
14–8	SDMODE	All 0s	SDRAM mode register. For SDRAM only. These bits specify the SDRAM mode register data to be written to the SDRAM array during power-up configuration. Note that the SDRAM mode register ‘opcode’ field is not specified and is forced to b’0_0000’ by the MPC8240 when the mode registers are written. Bits 14–12 CAS latency 000 Reserved 001 1 010 2 011 3 100 Reserved 101 Reserved 110 Reserved 111 Reserved Bit 11 Wrap type 0 Sequential. Default for MPC8240 1 Interleaved - Reserved Bits 10–8 Burst length 000 Reserved 001 Reserved 010 4 011 8 100 Reserved 101 Reserved 110 Reserved 111 Reserved

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Table 4-41. Bit Settings for MCCR4—0xFC (Continued)

Bits	Name	Reset Value	Description
7–4	ACTORW	0000	Activate to read/write interval. For SDRAM only. These bits control the number of clock cycles from an SDRAM-activate command until an SDRAM-read or SDRAM-write command is allowed. See Section 6.2.4, “SDRAM Power-On Initialization,” for more information. 0001 Reserved 0010 2 clocks (minimum for flow-through or registered data interfaces) 0011 3 clocks (minimum for in-line ECC/parity data interfaces) ... ... 1111 15 clocks 0000 16 clocks
3–0	BSTOPRE[6–9]	0000	Burst to precharge—bits 6–9. For SDRAM only. These bits, together with BSTOPRE[0–1] (bits 19–18 of MCCR4), and BSTOPRE[2–5] (bits 31–28 of MCCR3), control the open page interval. The page open duration counter is reloaded with BSTOPRE[0–9] every time the page is accessed (including page hits). When the counter expires, the open page is closed with a SDRAM-precharge bank command. See Chapter 6, “MPC8240 Memory Interface,” for more information.

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Chapter 5
PowerPC Processor Core

The MPC8240 contains an embedded version of the PowerPC 603e™ processor called the processor core. This chapter provides an overview of the basic functionality of the processor core. For detailed information regarding the processor refer to the following:

- *MPC603e & EC603e User's Manual* (those chapters that describe the programming model, cache model, memory management model, exception model, and instruction timing)
- *MPC603e & EC603e Microprocessor User's Manual Errata* (those sections that pertain to the programming model, cache model, memory management model, exception model, and instruction timing)
- *PowerPC™ Microprocessor Family: The Programming Environments for 32-Bit Microprocessors*

This section describes the details of the processor core, provides a block diagram showing the major functional units, and describes briefly how those units interact. At the end of this chapter, there is a section that outlines the detailed differences between the processor core and the MPC8240 processor.

The signals associated with the processor core are described in Chapter 2, "Signal Descriptions and Clocking."

5.1 Overview

The processor core is a low-power implementation of the PowerPC microprocessor family of reduced instruction set computing (RISC) microprocessors. The processor core implements the 32-bit portion of the PowerPC architecture, which supports 32-bit effective addresses.

Figure 5-1 is a block diagram of the processor core.

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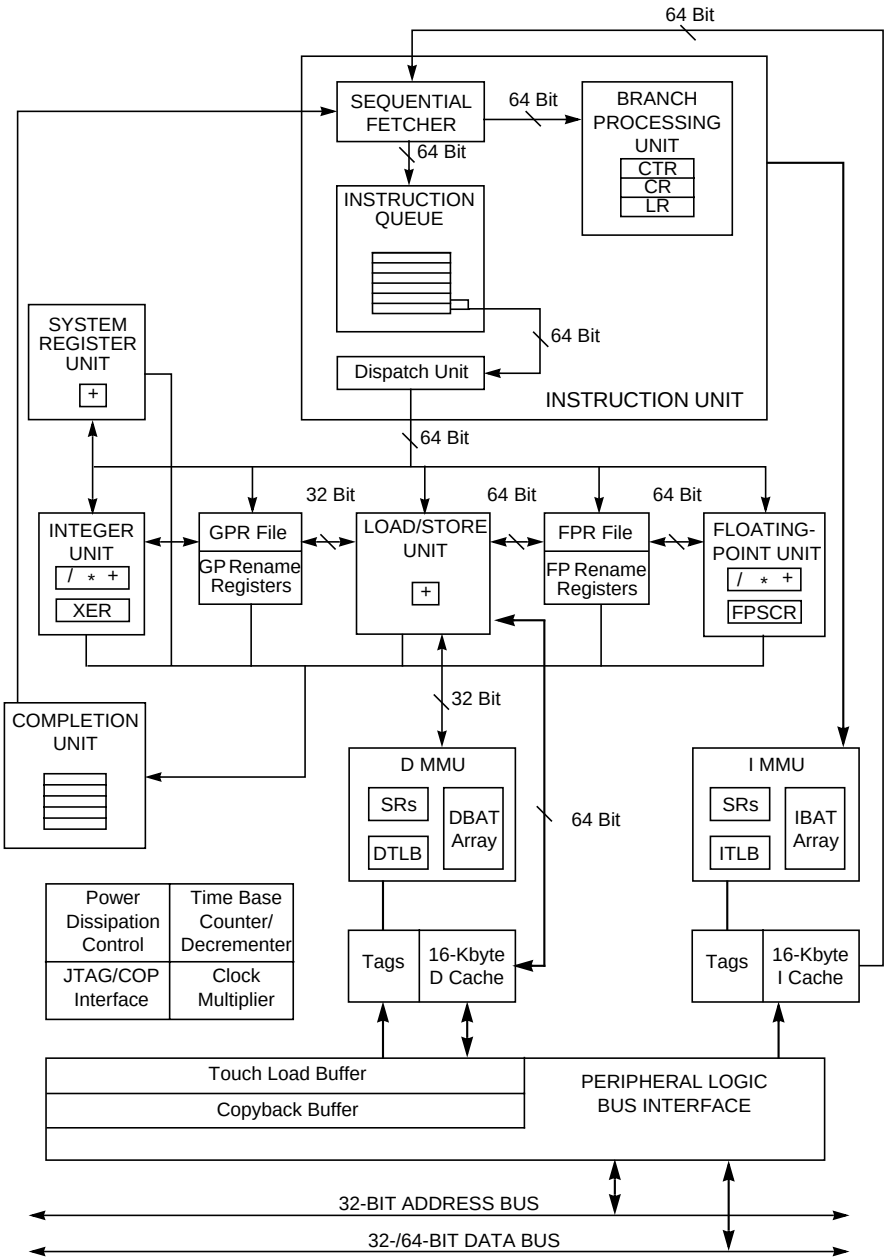

Figure 5-1. MPC8240 Integrated Processor Core Block Diagram

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The processor core is a superscalar processor that can issue and retire as many as three instructions per clock. Instructions can execute out of order for increased performance; however, the processor core makes completion appear sequential.

The processor core integrates five execution units—an integer unit (IU), a floating-point unit (FPU), a branch processing unit (BPU), a load/store unit (LSU), and a system register unit (SRU). The ability to execute five instructions in parallel and the use of simple instructions with rapid execution times yield high efficiency and throughput. Most integer instructions execute in one clock cycle. On the processor core, the FPU is pipelined so a single-precision multiply-add instruction can be issued and completed every clock cycle.

The processor core supports integer data types of 8, 16, and 32 bits, and floating-point data types of 32 and 64 bits.

The processor core provides separate on-chip, 16-Kbyte, four-way set-associative, physically addressed caches for instructions and data and on-chip instruction and data memory management units (MMUs). The MMUs contain 64-entry, two-way set-associative, data and instruction translation lookaside buffers (DTLB and ITLB) that provide support for demand-paged virtual memory address translation and variable-sized block translation. The TLBs and caches use a least recently used (LRU) replacement algorithm. The processor core also supports block address translation through the use of two independent instruction and data block address translation (IBAT and DBAT) arrays of four entries each. Effective addresses are compared simultaneously with all four entries in the BAT array during block translation. In accordance with the PowerPC architecture, if an effective address hits in both the TLB and BAT array, the BAT translation takes priority.

As an added feature to the MPC603e core, the MPC8240 can lock the contents of 1–3 ways in the instruction and data cache (or an entire cache). For example, this allows embedded applications to lock interrupt routines or other important (time-sensitive) instruction sequences into the instruction cache. It allows data to be locked into the data cache, which may be important to code that must have deterministic execution.

The processor core has a selectable 32- or 64-bit data bus and a 32-bit address bus. The processor core supports single-beat and burst data transfers for memory accesses and supports memory-mapped I/O operations.

5.2 PowerPC Processor Core Features

This section describes the major features of the processor core:

- High-performance, superscalar microprocessor
  - — As many as three instructions issued and retired per clock cycle
  - — As many as five instructions in execution per clock cycle
  - — Single-cycle execution for most instructions
  - — f FPU for all single-precision and most double-precision operations

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- Five independent execution units and two register files
  - — BPU featuring static branch prediction
  - — A 32-bit IU
  - — Fully IEEE 754-compliant FPU for both single- and double-precision operations
  - — LSU for data transfer between data cache and GPRs and FPRs
  - — SRU that executes condition register (CR), special-purpose register (SPR), and integer add/compare instructions
  - — Thirty-two GPRs for integer operands
  - — Thirty-two FPRs for single- or double-precision operands
- High instruction and data throughput
  - — Zero-cycle branch capability (branch folding)
  - — Programmable static branch prediction on unresolved conditional branches
  - — BPU that performs CR lookahead operations
  - — Instruction fetch unit capable of fetching two instructions per clock from the instruction cache
  - — A six-entry instruction queue that provides lookahead capability
  - — Independent pipelines with feed-forwarding that reduces data dependencies in hardware
  - — 16-Kbyte data cache—four-way set-associative, physically addressed, LRU replacement algorithm
  - — 16-Kbyte instruction cache—four-way set-associative, physically addressed, LRU replacement algorithm
  - — Cache write-back or write-through operation programmable on a per page or per block basis
  - — Address translation facilities for 4-Kbyte page size, variable block size, and 256-Mbyte segment size
  - — A 64-entry, two-way set-associative ITLB
  - — A 64-entry, two-way set-associative DTLB
  - — Four-entry data and instruction BAT arrays providing 128-Kbyte to 256-Mbyte blocks
  - — Software table search operations and updates supported through fast trap mechanism
  - — 52-bit virtual address; 32-bit physical address

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- Facilities for enhanced system performance
  - A 32- or 64-bit split-transaction internal data bus interface to the peripheral logic bus with bursting
  - Support for one-level address pipelining and out-of-order bus transactions
  - Hardware support for misaligned little-endian accesses
  - Cofigurable processor bus frequency multipliers as defined in the *MPC8240 Integrated Processor Hardware Specifications.*
- Integrated power management
  - Three power-saving modes: doze, nap, and sleep
  - Automatic dynamic power reduction when internal functional units are idle
- Deterministic behavior and debug features
  - On-chip cache locking options for the instruction and data caches (1–3 ways or the entire cache contents can be locked)
  - In-system testability and debugging features through JTAG and boundary-scan capability

Figure 5-1 shows how the execution units (IU, BPU, FPU, LSU, and SRU) operate independently and in parallel. Note that this is a conceptual diagram and does not attempt to show how these features are physically implemented on the chip.

5.2.1 Instruction Unit

As shown in Figure 5-1, the instruction unit, which contains a fetch unit, instruction queue, dispatch unit, and the BPU, provides centralized control of instruction flow to the execution units. The instruction unit determines the address of the next instruction to be fetched based on information from the sequential fetcher and from the BPU.

The instruction unit fetches the instructions from the instruction cache into the instruction queue. The BPU extracts branch instructions from the fetcher and uses static branch prediction on unresolved conditional branches to allow the instruction unit to fetch instructions from a predicted target instruction stream while a conditional branch is evaluated. The BPU folds out branch instructions for unconditional branches or conditional branches unaffected by instructions in progress in the execution pipeline.

Instructions issued beyond a predicted branch do not complete execution until the branch is resolved, preserving the programming model of sequential execution. If any of these instructions are to be executed in the BPU, they are decoded but not issued. Instructions to be executed by the IU, FPU, LSU, and SRU are issued and allowed to complete up to the register write-back stage. Write-back is allowed when a correctly predicted branch is resolved, and instruction execution continues without interruption on the predicted path. If branch prediction is incorrect, the instruction unit flushes all predicted path instructions, and instructions are issued from the correct path.

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5.2.2 Instruction Queue and Dispatch Unit

The instruction queue (IQ), shown in Figure 5-1, holds as many as six instructions and loads up to two instructions from the instruction unit during a single cycle. The instruction fetch unit continuously loads as many instructions as the space in the IQ allows. Instructions are dispatched to their respective execution units from the dispatch unit at a maximum rate of two instructions per cycle. Reservation stations at the IU, FPU, LSU, and SRU facilitate instruction dispatch to those units. The dispatch unit checks for source and destination register dependencies, determines dispatch serializations, and inhibits subsequent instruction dispatching as required. Section 5.7, "Instruction Timing," describes instruction dispatch in detail.

5.2.3 Branch Processing Unit (BPU)

The BPU receives branch instructions from the fetch unit and performs CR lookahead operations on conditional branches to resolve them early, achieving the effect of a zero-cycle branch in many cases.

The BPU uses a bit in the instruction encoding to predict the direction of the conditional branch. Therefore, when an unresolved conditional branch instruction is encountered, instructions are fetched from the predicted target stream until the conditional branch is resolved.

The BPU contains an adder to compute branch target addresses and three user-control registers—the link register (LR), the count register (CTR), and the condition register (CR). The BPU calculates the return pointer for subroutine calls and saves it into the LR for certain types of branch instructions. The LR also contains the branch target address for the Branch Conditional to Link Register (**bclrx**) instruction. The CTR contains the branch target address for the Branch Conditional to Count Register (**bcctrx**) instruction. The contents of the LR and CTR can be copied to or from any GPR. Because the BPU uses dedicated registers rather than GPRs or FPRs, execution of branch instructions is largely independent from execution of other instructions.

5.2.4 Independent Execution Units

The PowerPC architecture's support for independent execution units allows implementation of processors with out-of-order instruction execution. For example, because branch instructions do not depend on GPRs or FPRs, branches can often be resolved early, eliminating stalls caused by taken branches.

In addition to the BPU, the processor core provides four other execution units and a completion unit, which are described in the following sections.

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5.2.4.1 Integer Unit (IU)

The IU executes all integer instructions. The IU executes one integer instruction at a time, performing computations with its arithmetic logic unit (ALU), multiplier, divider, and XER register. Most integer instructions are single-cycle instructions. Thirty-two general-purpose registers are provided to support integer operations. Stalls due to contention for GPRs are minimized by the automatic allocation of rename registers. The processor core writes the contents of the rename registers to the appropriate GPR when integer instructions are retired by the completion unit.

5.2.4.2 Floating-Point Unit (FPU)

The FPU contains a single-precision multiply-add array and the floating-point status and control register (FPSCR). The multiply-add array allows the processor to efficiently implement multiply and multiply-add operations. The FPU is pipelined so that single-precision instructions and double-precision instructions can be issued back-to-back. Thirty-two floating-point registers are provided to support floating-point operations. Stalls due to contention for FPRs are minimized by the automatic allocation of rename registers. The processor writes the contents of the rename registers to the appropriate FPR when floating-point instructions are retired by the completion unit.

The processor supports all IEEE 754 floating-point data types (normalized, denormalized, NaN, zero, and infinity) in hardware, eliminating the latency incurred by software exception routines.

5.2.4.3 Load/Store Unit (LSU)

The LSU executes all load and store instructions and provides the data transfer interface between the GPRs, FPRs, and the cache/memory subsystem. The LSU calculates effective addresses, performs data alignment, and provides sequencing for load/store string and multiple instructions.

Load and store instructions are issued and translated in program order; however, the actual memory accesses can occur out of order. Synchronizing instructions are provided to enforce strict ordering where needed.

Cacheable loads, when free of data dependencies, execute in an out-of-order manner with a maximum throughput of one per cycle and a two-cycle total latency. Data returned from the cache is held in a rename register until the completion logic commits the value to a GPR or FPR. Store operations do not occur until a predicted branch is resolved. They remain in the store queue until the completion logic signals that the store operation is definitely to be completed to memory.

The processor core executes store instructions with a maximum throughput of one per cycle and a three-cycle total latency. The time required to perform the actual load or store operation varies depending on whether the operation involves the cache, system memory, or an I/O device.

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5.2.4.4 System Register Unit (SRU)

The SRU executes various system-level instructions, including condition register logical operations and move to/from special-purpose register instructions, and integer add/compare instructions. Because SRU instructions affect modes of processor operation, most SRU instructions are completion-serialized. That is, the instruction is held for execution in the SRU until all prior instructions issued have completed. Results from completion-serialized instructions executed by the SRU are not available or forwarded for subsequent instructions until the instruction completes.

5.2.5 Completion Unit

The completion unit tracks instructions from dispatch through execution, and then retires, or completes them in program order. Completing an instruction commits the processor core to any architectural register changes caused by that instruction. In-order completion ensures the correct architectural state when the processor core must recover from a mispredicted branch or any exception.

Instruction state and other information required for completion is kept in a first-in-first-out (FIFO) queue of five completion buffers. A single completion buffer is allocated for each instruction once it enters the dispatch unit. An available completion buffer is a required resource for instruction dispatch; if no completion buffers are available, instruction dispatch stalls. A maximum of two instructions per cycle are completed in order from the queue.

5.2.6 Memory Subsystem Support

The processor core supports cache and memory management through separate instruction and data MMUs (IMMU and DMMU). The processor core also provides dual 16-Kbyte instruction and data caches, and an efficient peripheral bus interface to facilitate access to main memory and other bus subsystems. The memory subsystem support functions are described in the following subsections.

5.2.6.1 Memory Management Units (MMUs)

The processor core's MMUs support up to 4 Petabytes (2^{52}) of virtual memory and 4 Gbytes (2^{32}) of physical memory (referred to as real memory in the PowerPC architecture specification) for instructions and data. The MMUs also control access privileges for these spaces on block and page granularities. Referenced and changed status is maintained by the processor for each page to assist implementation of a demand-paged virtual memory system. A key bit is implemented to provide information about memory protection violations prior to page table search operations.

The LSU calculates effective addresses for data loads and stores, performs data alignment to and from cache memory, and provides the sequencing for load and store string and multiple word instructions. The instruction unit calculates the effective addresses for instruction fetching.

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The MMUs translate effective addresses and enforce the protection hierarchy programmed by the operating system in relation to the supervisor/user privilege level of the access and in relation to the type of access—load or store.

5.2.6.2 Cache Units

The processor core provides independent 16-Kbyte, four-way set-associative instruction and data caches. The cache block size is 32 bytes. The caches are designed to adhere to a write-back policy, but the processor core allows control of cacheability, write policy, and memory coherency at the page and block levels. The caches use a least recently used (LRU) replacement algorithm.

The load/store and instruction fetch units provide the caches with the address of the data or instruction to be fetched. In the case of a cache hit, the cache returns two words to the requesting unit.

Note that the MPC8240 processor core has some additional cache locking functionality compared to the MPC603e. This is described in more detail in Section 5.4.2.3, “Cache Locking.”

5.2.6.3 Peripheral Logic Bus Interface

The MPC8240 contains an internal peripheral logic bus that interfaces the processor core to the peripheral logic. This internal bus is very similar in function to the external 60x bus interface on the MPC603e. In the case of the MPC8240, the central control unit (CCU) terminates all the transactions and internally directs all accesses to the appropriate peripheral (or memory) interface.

5.2.6.3.1 Peripheral Logic Bus Protocol

The processor core-to-peripheral logic interface includes a 32-bit address bus, a 32- or 64-bit data bus as well as control and information signals. The peripheral logic interface allows for address-only transactions as well as address and data transactions. The processor core control and information signals include the address arbitration, address start, address transfer, transfer attribute, address termination, data arbitration, data transfer, data termination, and processor state signals. Test and control signals provide diagnostics for selected internal circuits.

The peripheral logic interface supports bus pipelining, which allows the address tenure of one transaction to overlap the data tenure of another. PCI accesses to the memory space are monitored by the peripheral logic bus to allow the processor to snoop these accesses (provided PICR[27] is cleared).

5.2.6.3.2 Peripheral Logic Bus Data Transfers

As part of the peripheral logic bus interface, the processor core’s data bus is configured at power-up (by the value on the MDL[0] signal) to either a 32- or 64-bit width.

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When the processor is configured with a 32-bit data bus, memory accesses on the peripheral logic bus interface allow transfer sizes of 8, 16, 24, or 32 bits in one bus clock cycle. Data transfers occur in either single-beat transactions, or two-beat or eight-beat burst transactions, with a single-beat transaction transferring as many as 32 bits. Single- or double-beat transactions are caused by noncached accesses that access memory directly (that is, reads and writes when caching is disabled, caching-inhibited accesses, and stores in write-through mode). Eight-beat burst transactions, which always transfer an entire cache line (32 bytes), are initiated when a line is read from or written to memory.

When the peripheral logic bus interface is configured with a 64-bit data bus, memory accesses allow transfer sizes of 8, 16, 24, 32, or 64 bits in one bus clock cycle. Data transfers occur in either single-beat transactions or four-beat burst transactions. Single-beat transactions are caused by noncached accesses that access memory directly (that is, reads and writes when caching is disabled, caching-inhibited accesses, and stores in write-through mode). Four-beat burst transactions, which always transfer an entire cache line (32 bytes), are initiated when a line is read from or written to memory.

5.2.6.3.3 Peripheral Logic Bus Frequency

The core can operate at a variety of frequencies allowing the designer to trade off performance for power consumption. The processor core is clocked from a separate PLL, which is referenced to the peripheral logic PLL. This allows the microprocessor and the peripheral logic to operate at different frequencies while maintaining a synchronous bus interface.

5.3 Programming Model

The following subsections describe the PowerPC instruction set and addressing modes in general.

5.3.1 Register Set

This section describes the register organization in the processor core as defined by the three programming environments of the PowerPC architecture—the user instruction set architecture (UISA), the virtual environment architecture (VEA), and the operating environment architecture (OEA), as well as the MPC8240 core implementation-specific registers. Full descriptions of the basic register set defined by the PowerPC architecture are provided in Chapter 2, “PowerPC Register Set,” in The Programming Environments Manual.

The PowerPC architecture defines register-to-register operations for all computational instructions. Source data for these instructions is accessed from the on-chip registers or is provided as an immediate value embedded in the opcode. The three-register instruction format allows specification of a target register distinct from the two source registers, thus preserving the original data for use by other instructions and reducing the number of

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instructions required for certain operations. Data is transferred between memory and registers with explicit load and store instructions only.

Figure 5-2 shows the complete MPC8240 register set and the programming environment to which each register belongs. This figure includes both the PowerPC register set and the MPC8240-specific registers.

Note that there may be registers common to other PowerPC processors that are not implemented in the MPC8240's processor core. Unsupported Special Purpose Register (SPR) values are treated as follows:

- Any **mtspr** with an invalid SPR executes as a no-op.
- Any **mfspr** with an invalid SPR causes boundedly undefined results in the target register.

Conversely, some SPRs in the processor core may not be implemented at all or may not be implemented in the same way in other PowerPC processors.

5.3.1.1 PowerPC Register Set

The PowerPC UISA registers, shown in Figure 5-2, can be accessed by either user- or supervisor-level instructions. The general-purpose registers (GPRs) and floating-point registers (FPRs) are accessed through instruction operands. Access to registers can be explicit (that is, through the use of specific instructions for that purpose such as the **mtspr** and **mfspr** instructions) or implicit as part of the execution (or side effect) of an instruction. Some registers are accessed both explicitly and implicitly.

The number to the right of the register name indicates the number that is used in the syntax of the instruction operands to access the register (for example, the number used to access the XER is one). For more information on the PowerPC register set, refer to Chapter 2, "PowerPC Register Set," in The Programming Environments Manual.

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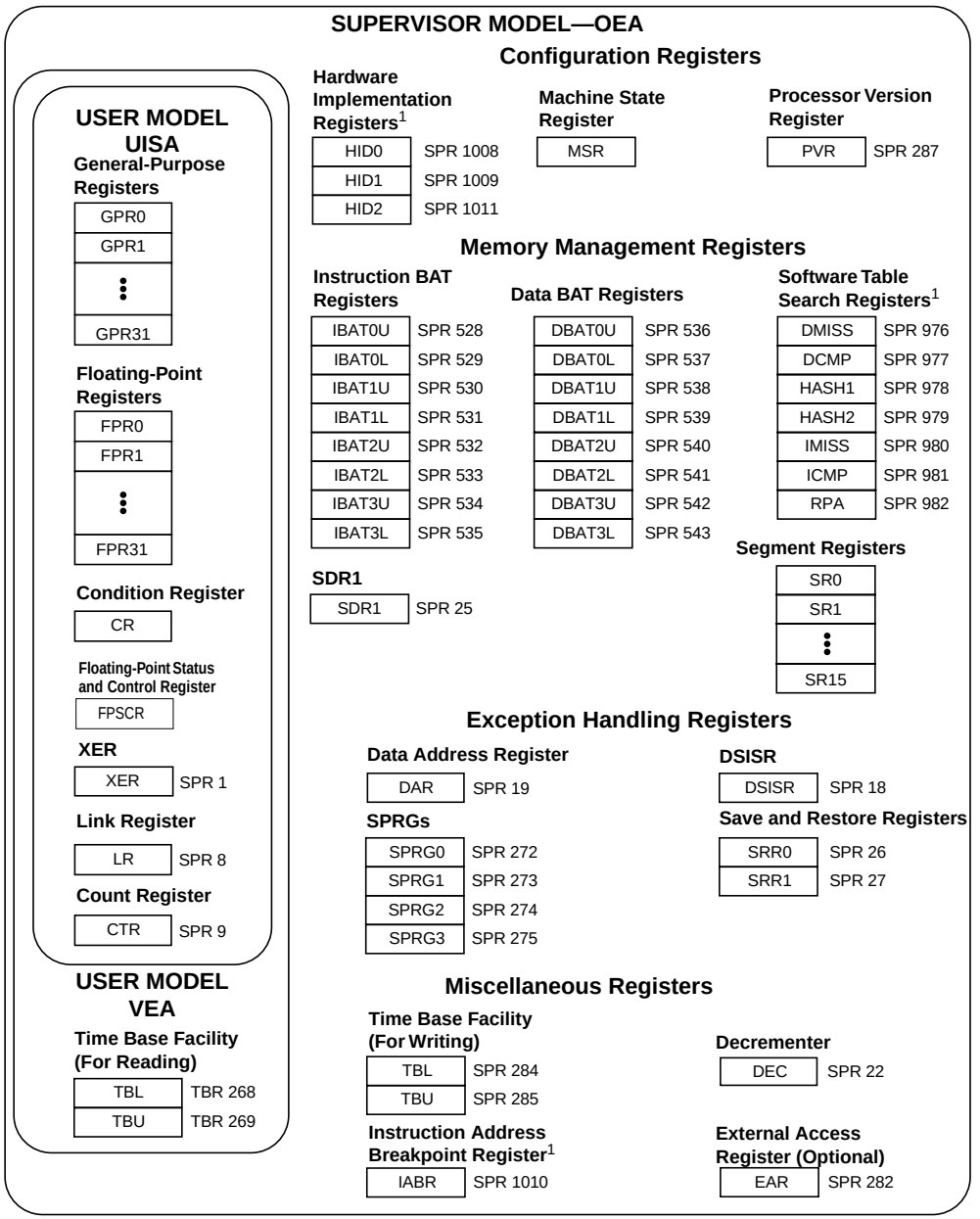

[1] These implementation–specific registers may not be supported by other PowerPC processors or processor cores.

Figure 5-2. MPC8240 Programming Model—Registers

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5.3.1.2 MPC8240-Specific Registers

The set of registers specific to the MPC603e are shown in Figure 5-2. Most of these are described in the MPC603e User's Manual and are implemented in the MPC8240 as follows:

- MMU software table search registers—DMISS, DCMP, HASH1, HASH2, IMISS, ICMP, and RPA. These registers facilitate the software required to search the page tables in memory.
- IABR—This register facilitates the setting of instruction breakpoints.

The hardware implementation-dependent registers (HIDx) are implemented differently in the MPC8240 as described in the following subsections.

5.3.1.2.1 Hardware Implementation-Dependent Register 0 (HID0)

The processor core's implementation of HID0 differs from the MPC603e User's Manual as follows:

- Bit 5, HID0[EICE], has been removed
- No support for pipeline tracking

Figure 5-3 shows the MPC8240 implementation of HID0. HID0 can be accessed with **mtspr** and **mfspr** using SPR1008.

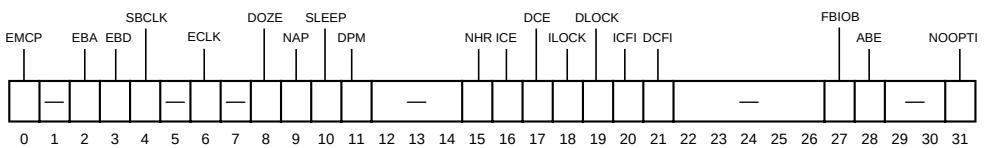

Figure 5-3. Hardware Implementation Register 0 (HID0)

Table 5-1 shows the bit definitions for HID0.

Table 5-1. HID0 Field Descriptions

Bits	Name	Description
0	EMCP	Enable machine check internal signal 0 The assertion of the internal $\overline{\text{mcp}}$ signal from the peripheral logic does not cause a machine check exception. 1 Enables the machine check exception based on assertion of the internal $\overline{\text{mcp}}$ signal from the peripheral logic to the processor core. Note that the machine check exception is further affected by MSR[ME], which specifies whether the processor checkstops or continues processing.
1	—	Reserved
2	EBA	Enable/disable internal peripheral bus (60x bus) address parity checking 0 Prevents address parity checking 1 Allows a address parity error to cause a checkstop if MSR[ME] = 0 or a machine check exception if MSR[ME] = 1 EBA and EBD let the processor operate with memory subsystems that do not generate parity.

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Table 5-1. HID0 Field Descriptions (Continued)

Bits	Name	Description
3	EBD	Enable internal peripheral bus (60x bus) data parity checking 0 Parity checking is disabled. 1 Allows a data parity error to cause a checkstop if MSR[ME] = 0 or a machine check exception if MSR[ME] = 1 EBA and EBD let the processor operate with memory subsystems that do not generate parity.
4	SBCLK	CKO output enable and clock type selection. When PMCR1[CKO_SEL] = 0, this bit is used in conjunction with HID0[ECLK] and the hard reset signals to configure CKO. See Table 5-2.
5	—	EICE bit on some other PowerPC devices This bit is not used in the MPC8240 (and so it is reserved).
6	ECLK	CKO output enable and clock type selection.When PMCR1[CKO_SEL] = 0, this bit is used in conjunction with HID0[SBCLK] and the hard reset signals to configure CKO. See Table 5-2.
7	—	PAR bit on some other PowerPC devices to disable precharge of $\overline{\text{ARTRY}}$ signal. This bit is not used in the MPC8240 (and so it is reserved).
8	DOZE	Doze mode enable. Operates in conjunction with MSR[POW]. [1] 0 Processor doze mode disabled. 1 Processor doze mode enabled. Doze mode is invoked by setting MSR[POW] while this bit is set. In doze mode, the PLL, time base, and snooping remain active.
9	NAP	Nap mode enable—Operates in conjunction with MSR[POW] [1] 0 Processor nap mode disabled 1 Processor nap mode enabled. Nap mode is invoked by setting MSR[POW] while this bit is set. When this occurs, the processor indicates that it is ready to enter nap mode. If the peripheral logic determines that the processor may enter nap mode (no more snooping of the internal buffers is required), the processor enters nap mode after several processor clocks. In nap mode, the PLL and the time base remain active. Note that the MPC8240 asserts the $\overline{\text{QACK}}$ output signal depending on the power-saving state of the peripheral logic, and not on the power-saving state of the processor core.
10	SLEEP	Sleep mode enable—Operates in conjunction with MSR[POW] [1] 0 Processor sleep mode disabled 1 Processor sleep mode enabled—Sleep mode is invoked by setting MSR[POW] while this bit is set. When this occurs, the processor indicates that it is ready to enter sleep mode. If the peripheral logic determines that the processor may enter sleep mode (no more snooping of the internal buffers is required), the processor enters sleep mode after several processor clocks. At this point, the system logic may turn off the PLL by first configuring PLL_CFG[0–4] to PLL bypass mode, and then disabling the internal sys_logic-clk signal. Note that the MPC8240 asserts the $\overline{\text{QACK}}$ output signal depending on the power-saving state of the peripheral logic, and not on the power-saving state of the processor core.
11	DPM	Dynamic power management enable [1] 0 Processor dynamic power management is disabled. 1 Functional units enter a low-power mode automatically if the unit is idle. This does not affect operational performance and is transparent to software or any external hardware.
12–14	—	Reserved
15	NHR	Not hard reset (software-use only)—Helps software distinguish a hard reset from a soft reset. 0 A hard reset occurred if software had previously set this bit. 1 A hard reset has not occurred. If software sets this bit after a hard reset, when a reset occurs and this bit remains set, software can detect that it was a soft reset.

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Table 5-1. HID0 Field Descriptions (Continued)

Bits	Name	Description
16	ICE	Instruction cache enable [2] 0 The instruction cache is neither accessed nor updated. All pages are accessed as if they were marked cache-inhibited (WIM = X1X). Potential cache accesses from the bus (snoop and cache operations) are ignored. In the disabled state for the L1 caches, the cache tag state bits are ignored, and all accesses are propagated to the bus as single-beat transactions. For these transactions, however, the processor reflects the original state of the I bit (from the MMU) to the peripheral logic block, regardless of cache disabled status. ICE is zero at power-up. 1 The instruction cache is enabled.
17	DCE	Data cache enable [2] 0 The data cache is neither accessed nor updated. All pages are accessed as if they were marked cache-inhibited (WIM = X1X). Potential cache accesses from the bus (snoop and cache operations) are ignored. In the disabled state, the cache tag state bits are ignored and all accesses are propagated to the bus as single-beat transactions. For those transactions, however, the processor reflects the original state of the I bit (from the MMU) to the peripheral logic block, regardless of cache disabled status. DCE is zero at power-up. 1 The data cache is enabled.
18	ILOCK	Instruction cache lock 0 Normal operation 1 Instruction cache is locked. A locked cache supplies data normally on a hit, but an access is treated as a cache-inhibited transaction on a miss. On a miss, the transaction to the bus is single-beat. To prevent locking during a cache access, an **isync** must precede the setting of ILOCK.
19	DLOCK	Data cache lock 0 Normal operation 1 Data cache is locked. A locked cache supplies data normally on a hit but an access is treated as a cache-inhibited transaction on a miss. On a miss, the transaction to the bus is single-beat. A snoop hit to a locked L1 data cache performs as if the cache were not locked. A cache block invalidated by a snoop remains invalid until the cache is unlocked. To prevent locking during a cache access, a sync must precede the setting of DLOCK.
20	ICFI	Instruction cache flash invalidate [2] 0 The instruction cache is not invalidated. The bit is cleared when the invalidation operation begins (usually the next cycle after the write operation to the register). The instruction cache must be enabled for the invalidation to occur. 1 An invalidate operation is issued that marks the state of each instruction cache block as invalid without writing back modified cache blocks to memory. Cache access is blocked during this time. Accesses to the cache from the peripheral logic bus are signaled as a miss during invalidate-all operations. Setting ICFI clears all the valid bits of the blocks and the PLRU bits to point to way L0 of each set. For 603e processors, the proper use of the ICFI and DCFI bits is to set them and clear them with two consecutive **mtspr** operations.
21	DCFI	Data cache flash invalidate [2] 0 The data cache is not invalidated. The bit is cleared when the invalidation operation begins (usually the next cycle after the write operation to the register). The data cache must be enabled for the invalidation to occur. 1 An invalidate operation is issued that marks the state of each data cache block as invalid without writing back modified cache blocks to memory. Cache access is blocked during this time. Accesses to the cache from the peripheral logic bus are signaled as a miss during invalidate-all operations. Setting DCFI clears all the valid bits of the blocks and the PLRU bits so that they point to way L0 of each set. For 603e processors, the proper use of the ICFI and DCFI bits is to set them and clear them with two consecutive **mtspr** operations.
22–23	—	Reserved

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Table 5-1. HID0 Field Descriptions (Continued)

Bits	Name	Description
24	—	IFEM bit on some other PowerPC devices This bit is not used in the MPC8240 (and so it is reserved).
25–26	—	Reserved
27	FBIOB	Force branch indirect on bus 0 Register indirect branch targets are fetched normally 1 Forces register indirect branch targets to be fetched externally.
28	—	Reserved—Used as address broadcast enable bit on some other PowerPC devices
29–30	—	Reserved
31	NOOPTI	No-op the data cache touch instructions 0 The **dcbt** and **dcbtst** instructions are enabled. 1 The **dcbt** and **dcbtst** instructions are no-oped globally.

1 See Chapter 9, "Power Management," of the MPC603e User's Manual for more information.

2 See Chapter 3, "Instruction and Data Cache Operation," of the MPC603e User's Manual for more information.

Table 5-2 shows how HID0[SBCLK], HID0[ECLK], and the hard reset signals are used to configure CKO when PMCR1[CKO_SEL] = 0. When PMCR1[CKO_SEL] = 1, the CKO_MODE field of PMCR1 determines the signal driven on CKO. Note that the initial value of PMCR1[CKO_SEL] is determined by the value on the $\overline{\text{AS}}$ signal at the negation of $\overline{\text{HRST\_CPU}}$. See Section 2.2.7.8, "Debug Clock (CKO)—Output," and Section 2.4, "Configuration Signals Sampled at Reset," for more information.

Table 5-2. HID0[BCLK] and HID0[ECLK] CKO Signal Configuration

$\overline{\text{HRST\_CPU}}$ and $\overline{\text{HRST\_CTRL}}$	HID0[ECLK]	HID0[SBCLK]	Signal Driven on CKO
Asserted	x	x	Processor core clock
Negated	0	0	High impedance
Negated	0	1	sys-logic-clk divided by 2
Negated	1	0	Processor core clock
Negated	1	1	sys-logic-clk

5.3.1.2.2 Hardware Implementation-Dependent Register 1 (HID1)

The MPC8240 implementation of HID1 is shown in Figure 5-4.

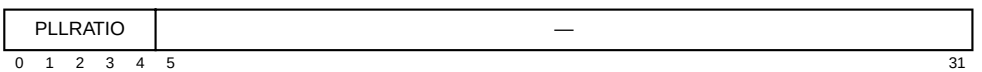

Figure 5-4. Hardware Implementation Register 1 (HID1)

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Table 5-3 shows the bit definitions for HID1.

Table 5-3. HID1 Field Descriptions

Bits	Name	Function
0–4	PLLRATIO	PLL configuration processor core frequency ratio—This read-only field is determined by the value on the PLL_CFG[0–4] signals during reset and the processor-to-memory clock frequency ratio defined by that PLL_CFG[0–4] value. See MPC8240 Hardware Specification for a listing of supported settings. Note that multiple settings of the PLL_CFG[0–4] signals can map to the same PLLRATIO value. Thus, system software cannot read the PLLRATIO value and associate it with a unique PLL_CFG[0–4] value.
5–31	—	Reserved

5.3.1.2.3 Hardware Implementation-Dependent Register 2 (HID2)

The processor core implements an additional hardware implementation-dependent register as shown in Figure 5-5, not described in the *MPC603e User's Manual*.

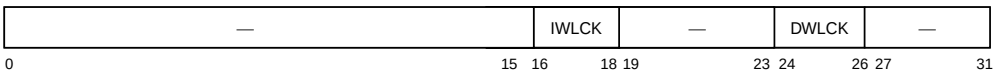

Figure 5-5. Hardware Implementation-Dependent Register 2 (HID2)

Table 5-4 describes the HID2 fields.

Table 5-4. HID2 Field Descriptions

Bits	Name	Function
0–15	—	Reserved
16–18	IWLCK	Instruction cache way lock—Useful for locking blocks of instructions into the instruction cache for time-critical applications where deterministic behavior is required. Refer to Section 5.4.2.3, "Cache Locking," for more information.
19–23	—	Reserved
24–26	DWLCK	Data cache way lock—Useful for locking blocks of data into the data cache for time-critical applications where deterministic behavior is required. Refer to Section 5.4.2.3, "Cache Locking," for more information.
27–31	—	Reserved

5.3.1.2.4 Processor Version Register (PVR)

Software can identify the MPC8240's processor core by reading the processor version register (PVR). The MPC8240's processor version number is 0x0081; the processor revision level starts at 0x0100 and is incremented for each revision of the chip. This information is useful for data cache flushing routines for identifying the size of the cache and identifying this processor as one that supports cache locking.

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5.3.2 PowerPC Instruction Set and Addressing Modes

All PowerPC instructions are encoded as single-word (32-bit) opcodes. Instruction formats are consistent among all instruction types, permitting efficient decoding to occur in parallel with operand accesses. This fixed instruction length and consistent format greatly simplifies instruction pipelining.

5.3.2.1 Calculating Effective Addresses

The effective address (EA) is the 32-bit address computed by the processor when executing a memory access or branch instruction or when fetching the next sequential instruction.

The PowerPC architecture supports two simple memory addressing modes:

- EA = (**r**A|0) + offset (including offset = 0) (register indirect with immediate index)
- EA = (**r**A|0) +7 **r**B (register indirect with index)

These simple addressing modes allow efficient address generation for memory accesses. Calculation of the effective address for aligned transfers occurs in a single clock cycle.

For a memory access instruction, if the sum of the effective address and the operand length exceeds the maximum effective address, the memory operand is considered to wrap around from the maximum effective address to effective address 0.

Effective address computations for both data and instruction accesses use 32-bit unsigned binary arithmetic. A carry from bit 0 is ignored in 32-bit implementations.

In addition to the functionality of the MPC603e, the MPC8240 has additional hardware support for misaligned little-endian accesses. Except for string/multiple load and store instructions, little-endian load/store accesses not on a word boundary generate exceptions under the same circumstances as big-endian requests.

5.3.2.2 PowerPC Instruction Set

The PowerPC instructions are divided into the following categories:

- Integer instructions—These include computational and logical instructions.
  - — Integer arithmetic — divide instructions execute with a shorter latency as described in Section 5.7, “Instruction Timing.”
  - — Integer compare
  - — Integer logical
  - — Integer rotate and shift
- Floating-point instructions—These include floating-point computational instructions, as well as instructions that affect the FPSCR.
  - — Floating-point arithmetic
  - — Floating-point multiply/add
  - — Floating-point rounding and conversion

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  - — Floating-point compare
  - — Floating-point status and control
- Load/store instructions—These include integer and floating-point load and store instructions.
  - — Integer load and store
  - — Integer load and store with byte reverse
  - — Integer load and store string/multiple
  - — Floating-point load and store
- Flow control instructions—These include branching instructions, condition register logical instructions, trap instructions, and other synchronizing instructions that affect the instruction flow.
  - — Branch and trap
  - — Condition register logical
  - — Primitives used to construct atomic memory operations (**lwarx** and **stwcx**.)
  - — Synchronize
- Processor control instructions—These instructions are used for synchronizing memory accesses and management of caches, TLBs, and the segment registers.
  - — Move to/from SPR
  - — Move to/from MSR
  - — Instruction synchronize
- Memory control instructions—These provide control of caches, TLBs, and segment registers.
  - — Supervisor-level cache management
  - — User-level cache management
  - — Segment register manipulation
  - — TLB management

Note that this grouping of the instructions does not indicate which execution unit executes a particular instruction or group of instructions.

Integer instructions operate on byte, half-word, and word operands. The PowerPC architecture uses instructions that are four bytes long and word-aligned. It provides for byte, half-word, and word operand loads and stores between memory and a set of 32 GPRs. Floating-point instructions operate on single-precision (one word) and double-precision (one double word) floating-point operands. It also provides for word and double-word operand loads and stores between memory and a set of 32 floating-point registers (FPRs).

Computational instructions do not modify memory. To use a memory operand in a computation and then modify the same or another memory location, the memory contents must be loaded into a register, modified, and then written back to the target location with

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separate instructions. Decoupling computational instructions from memory accesses increases throughput by facilitating pipelining.

PowerPC processors follow the program flow when they are in the normal execution state. However, the flow of instructions can be interrupted directly by the execution of an instruction or by an asynchronous event. Either kind of exception may cause one of several components of the system software to be invoked.

5.3.2.3 MPC8240 Implementation-Specific Instruction Set

The MPC8240 processor core instruction set is defined as follows:

- The processor core provides hardware support for all 32-bit PowerPC instructions.
- The processor core provides two implementation-specific instructions used for software table search operations following TLB misses:
  - Load Data TLB Entry (**tlbld**)
  - Load Instruction TLB Entry (**tlbli**)
- The processor core implements the following instructions defined as optional by the PowerPC architecture:
  - Floating Select (**fsel**)
  - Floating Reciprocal Estimate Single-Precision (**fres**)
  - Floating Reciprocal Square Root Estimate (**frsqrte**)
  - Store Floating-Point as Integer Word Indexed (**stfiwx**)
  - External Control In Word Indexed (**eciwx**)
  - External Control Out Word Indexed (**ecowx**)

The MPC8240 does not provide the hardware support for misaligned **eciwx** and **ecowx** instructions provided by the MPC603e processor. An alignment exception is taken if these instructions are not word-aligned.

5.4 Cache Implementation

The MPC8240 processor core has separate data and instruction caches. The cache implementation is described in the following sections.

5.4.1 PowerPC Cache Model

The PowerPC architecture does not define hardware aspects of cache implementations. For example, some PowerPC processors, including the MPC8240's processor core, have separate instruction and data caches (Harvard architecture); others, such as the PowerPC 601® microprocessor implement a unified cache.

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PowerPC microprocessors control the following memory access modes on a page or block basis:

- Write-back/write-through mode
- Caching-inhibited mode
- Memory coherency

The PowerPC cache management instructions provide a means by which the application programmer can affect the cache contents.

5.4.2 MPC8240 Implementation-Specific Cache Implementation

As shown in Figure 5-1, the caches provide a 64-bit interface to the instruction fetch unit and load/store unit. The surrounding logic selects, organizes, and forwards the requested information to the requesting unit. Write operations to the cache can be performed on a byte basis, and a complete read-modify-write operation to the cache can occur in each cycle.

Each cache block contains eight contiguous words from memory that are loaded from an 8-word boundary (that is, bits A27–A31 of the effective addresses are zero); thus, a cache block never crosses a page boundary. Misaligned accesses across a page boundary can incur a performance penalty.

The cache blocks are loaded in to the processor core in four beats of 64 bits each. The burst load is performed as critical double word first.

To ensure coherency among caches in a multiprocessor (or multiple caching-device) implementation, the processor core implements the MEI protocol. These three states, modified, exclusive, and invalid, indicate the state of the cache block as follows:

- Modified—The cache block is modified with respect to system memory; that is, data for this address is valid only in the cache and not in system memory.
- Exclusive—This cache block holds valid data that is identical to the data at this address in system memory. No other cache has this data.
- Invalid—This cache block does not hold valid data.

5.4.2.1 Data Cache

As shown in Figure 5-6, the data cache is configured as 128 sets of four blocks each. Each block consists of 32 bytes, two state bits, and an address tag. The two state bits implement the three-state MEI (modified/exclusive/invalid) protocol. Each block contains eight 32-bit words. Note that the PowerPC architecture defines the term ‘block’ as the cacheable unit. For the MPC8240’s processor core, the block size is equivalent to a cache line.

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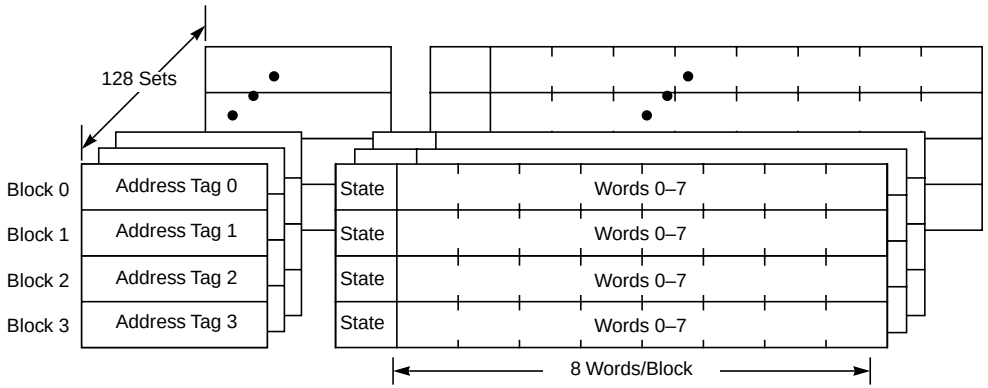

Figure 5-6. Data Cache Organization

Because the processor core data cache tags are single-ported, simultaneous load or store and snoop accesses cause resource contention. Snoop accesses have the highest priority and are given first access to the tags, unless the snoop access coincides with a tag write, in which case the snoop is retried and must rearbitrate for access to the cache. Loads or stores that are deferred due to snoop accesses are executed on the clock cycle following the snoop.

Because the caches on the processor core are write-back caches, the predominant type of transaction to the memory subsystem for most applications is burst-read memory operations, followed by burst-write memory operations, and single-beat (noncacheable or write-through) memory read and write operations. When a cache block is filled with a burst read, the critical double word is simultaneously written to the cache and forwarded to the requesting unit, thus minimizing stalls due to load delays.

Additionally, there can be address-only operations, variants of the burst and single-beat operations, (for example, global memory operations that are snooped and atomic memory operations), and address retry activity (for example, when a snooped read access hits a modified line in the cache). Note that all memory subsystem references are performed by the processor core to the internal peripheral logic bus on the MC8240.

The address and data buses of the internal peripheral logic bus operate independently to support pipelining and split transactions during memory accesses. The processor core pipelines its own transactions to a depth of one level.

Typically, memory accesses are weakly ordered—sequences of operations, including load/store string and multiple instructions, do not necessarily complete in the order they begin—maximizing the efficiency of the internal bus without sacrificing coherency of the data. The processor core allows pending read operations to precede previous store operations (except when a dependency exists, or in cases where a non-cacheable access is performed), and provides support for a write operation to proceed a previously queued read data tenure (for example, allowing a snoop push to be enveloped by the address and data

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tenures of a read operation). Because the processor can dynamically optimize run-time ordering of load/store traffic, overall performance is improved.

5.4.2.2 Instruction Cache

The instruction cache also consists of 128 sets of four blocks—each block consists of 32 bytes, an address tag, and a valid bit. The instruction cache may not be written to except through a block fill operation caused by a cache miss. In the processor core, internal access to the instruction cache is blocked only until the critical load completes.

The processor core supports instruction fetching from other instruction cache lines following the forwarding of the critical first double word of a cache line load operation. The processor core's instruction cache is blocked only until the critical load completes (hits under reloads allowed). Successive instruction fetches from the cache line being loaded are forwarded, and accesses to other instruction cache lines can proceed during the cache line load operation.

The instruction cache is not snooped, and cache coherency must be maintained by software. A fast hardware invalidation capability is provided to support cache maintenance. The organization of the instruction cache is very similar to the data cache shown in Figure 5-6.

5.4.2.3 Cache Locking

The processor core supports cache locking, which is the ability to prevent some or all of a microprocessor's instruction or data cache from being overwritten. Cache entries can be locked for either an entire cache or for individual ways within the cache. Entire data cache locking is enabled by setting HID0[DLOCK], and entire instruction cache locking is enabled by setting HID0[ILOCK]. For more information, refer to *Cache Locking on the G2 Core* application note (order number: AN1767/D). Cache way locking is controlled by the IWLCK and DWLCK bits of HID2.

5.4.2.3.1 Entire Cache Locking

When an entire cache is locked, hits within the cache are supplied in the same manner as hits to an unlocked cache. Any access that misses in the cache is treated as a cache-inhibited access. Cache entries that are invalid at the time of locking will remain invalid and inaccessible until the cache is unlocked. Once the cache has been unlocked, all entries (including invalid entries) are available. Entire cache locking is inefficient if the number of instructions or the size of data to be locked is small compared to the cache size.

5.4.2.3.2 Way Locking

Locking only a portion of the cache is accomplished by locking ways within the cache. Locking always begins with the first way (way0) and is sequential. That is, it is valid to lock ways 0, 1, and 2 but it is not possible to lock just way0 and way2. When using way locking at least one way must be left unlocked. The maximum number of lockable ways is three.

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Unlike entire cache locking, invalid entries in a locked way are accessible and available for data placement. As hits to the cache fill invalid entries within a locked way, the entries become valid and locked. This behavior differs from entire cache locking where nothing is placed in the cache, even if invalid entries exist in the cache. Unlocked ways of the cache behave normally.

5.4.3 Cache Coherency

The central control unit (CCU) manages the cache coherency within the MPC8240. It responds to all accesses generated by the processor core and causes the snooping of the addresses in the internal buffers as necessary. Also, the CCU generates snoop transactions on the peripheral logic bus to allow the processor to snoop accesses between the PCI interface and memory. Refer to Chapter 7, "PCI Bus Interface," for more detailed information about the internal address and data buffers in the MPC8240.

5.4.3.1 CCU Responses to Processor Transactions

The processor core generates various types of read and write accesses as well as address-only transactions. Table 5-5 shows all the types of internal transactions performed by the processor core and the CCU responses.

Table 5-5. CCU Responses to Processor Transactions

Processor Transaction	CCU Response
Read	Directs read to appropriate interface
Read-with-intent-to-modify	Directs read to appropriate interface
Read atomic	Directs read to appropriate interface
Read-with-intent-to-modify-atomic	Directs read to appropriate interface
Write-with-flush	Directs write to appropriate interface
Write-with-kill	Directs write to appropriate interface
Write-with-flush-atomic	Directs write to appropriate interface
sync	CCU buffers are flushed.
eieio	CCU buffers are flushed.
Kill block (generated by **dcbz** instruction when the addressed block has either the E or M bits set)	CCU buffers are snooped.
icbi	CCU buffers are snooped.
Read-with-no-intent-to-cache	Directs read to appropriate interface
Clean	CCU takes no further action.
Flush	CCU takes no further action.
tlbie	CCU takes no further action.
lwarx, reservation set	CCU takes no further action. (The MPC8240 does not support atomic references in PCI memory space.)

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Table 5-5. CCU Responses to Processor Transactions (Continued)

Processor Transaction	CCU Response
stwcx., reservation set	CCU takes no further action. (The MPC8240 does not support atomic references in PCI memory space.)
tlbsync	CCU takes no further action.
Graphic write (**ecowx**)	Processor transaction error. Machine check signalled to processor core (if enabled)
Graphic read (**eciwx**)	Processor transaction error. Machine check signalled to processor core (if enabled)

5.4.3.2 Processor Responses to PCI-to-Memory Transactions

The CCU controls the data flow between the PCI interface and the memory interface. One of its functions is to broadcast these transactions on the peripheral logic bus so that the processor core can snoop the L1 cache as needed (if snooping is enabled). Table 5-5 shows all the types of transactions reflected by the CCU to the processor core for snooping.

Table 5-6. Transactions Reflected to the Processor for Snooping

Snooped Transaction	Condition Detected by CCU	Processor Response
Read	Non-locked PCI read from memory	All burst reads observed on the bus are snooped as if they were writes, causing the addressed cache block to be flushed. A read marked as global causes the following responses: • If the addressed block in the cache is invalid, the processor takes no action. • If the addressed block in the cache is in the exclusive state, the block is invalidated. • If the addressed block in the cache is in the modified state, the block is flushed to memory and the block is invalidated.
Read-with-intent-to-modify (RWITM)-atomic	Locked PCI read from memory	A RWITM operation is issued to acquire exclusive use of a memory location for the purpose of modifying it. • If the addressed block is invalid, the processor takes no action. • If the addressed block in the cache is in the exclusive state, the processor changes the state of the cache block to invalid. • If the addressed block in the cache is in the modified state, the block is flushed to memory and the block is invalidated.

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Table 5-6. Transactions Reflected to the Processor for Snooping (Continued)

Snooped Transaction	Condition Detected by CCU	Processor Response
Write-with-flush Write-with-flush-atomic	Non-locked PCI write to memory or locked PCI write to memory, respectively	• If the addressed block is in the exclusive state, the snoop forces the state of the addressed block to invalid. • If the addressed block is in the modified state, the snoop causes a push of the modified block out of the cache to memory and changes the state of the block to invalid.
Write-with-kill	Locked or non-locked PCI write with invalidate to memory	In a write-with-kill operation, the processor snoops the cache for a copy of the addressed block. If one is found the cache block is forced to the I state, killing modified data that may have been in the block.

5.5 Exception Model

This section describes the PowerPC exception model and implementation-specific details of the MPC8240 core.

5.5.1 PowerPC Exception Model

The PowerPC exception mechanism allows the processor to change to supervisor state as a result of external signals, errors, or unusual conditions arising in the execution of instructions. When exceptions occur, information about the state of the processor is saved to certain registers and the processor begins execution at an address (exception vector) predetermined for each exception. Processing of exceptions occurs in supervisor mode.

Although multiple exception conditions can map to a single exception vector, a more specific condition may be determined by examining a register associated with the exception. For example, the DSISR identifies instructions that cause a DSI exception. Additionally, some exception conditions can be explicitly enabled or disabled by software.

The PowerPC architecture requires that exceptions be handled in program order; therefore, although a particular implementation may recognize exception conditions out of order, exceptions are taken in strict order. When an instruction-caused exception is recognized, any unexecuted instructions that appear earlier in the instruction stream, including any that have not yet entered the execute stage, are required to complete before the exception is taken. Any exceptions caused by those instructions are handled first. Likewise, exceptions that are asynchronous and precise are recognized when they occur, but are not handled until the instruction currently in the completion stage successfully completes execution or generates an exception, and the completed store queue is emptied.

Unless a catastrophic condition causes a system reset or machine check exception, only one exception is handled at a time. If, for example, a single instruction encounters multiple exception conditions, those conditions are handled sequentially. After the exception handler handles an exception, the instruction execution continues until the next exception condition

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is encountered. However, in many cases there is no attempt to re-execute the instruction. This method of recognizing and handling exception conditions sequentially guarantees that exceptions are recoverable.

Exception handlers should save the information stored in SRR0 and SRR1 early to prevent the program state from being lost due to a system reset or machine check exception or to an instruction-caused exception in the exception handler. SRR0 and SRR1 should also be saved before enabling external interrupts.

The PowerPC architecture supports four types of exceptions:

- Synchronous, precise—These are caused by instructions. All instruction-caused exceptions are handled precisely; that is, the machine state at the time the exception occurs is known and can be completely restored. This means that (excluding the trap and system call exceptions) the address of the faulting instruction is provided to the exception handler and neither the faulting instruction nor subsequent instructions in the code stream will complete execution before the exception is taken. Once the exception is processed, execution resumes at the address of the faulting instruction (or at an alternate address provided by the exception handler). When an exception is taken due to a trap or system call instruction, execution resumes at an address provided by the handler.
- Synchronous, imprecise—The PowerPC architecture defines two imprecise floating-point exception modes, recoverable and nonrecoverable. These are not implemented on the MPC8240.
- Asynchronous, maskable—The external interrupt ($\overline{int}$), system management interrupt ($\overline{SMI}$), and decrementer interrupts are maskable asynchronous exceptions. When these exceptions occur, their handling is postponed until the next instruction and any exceptions associated with that instruction complete execution. If no instructions are in the execution units, the exception is taken immediately upon determination of the correct restart address (for loading SRR0).
- Asynchronous, nonmaskable—There are two nonmaskable asynchronous exceptions— system reset and the machine check exception. These exceptions may not be recoverable, or may provide a limited degree of recoverability. All exceptions report recoverability through MSR[RI].

5.5.2 MPC8240 Implementation-Specific Exception Model

As specified by the PowerPC architecture, all processor core exceptions can be described as either precise or imprecise and either synchronous or asynchronous. Asynchronous exceptions (some of which are maskable) are caused by events external to the processor's execution. Synchronous exceptions, which are all handled precisely by the processor core, are caused by instructions. The processor core exception classes are shown in Table 5-7.

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Table 5-7. Exception Classifications for the Processor Core

Synchronous/Asynchronous	Precise/Imprecise	Exception Type
Asynchronous, nonmaskable	Imprecise	Machine check System reset
Asynchronous, maskable	Precise	External interrupt Decrementer System management interrupt
Synchronous	Precise	Instruction-caused exceptions

Although exceptions have other characteristics as well, such as whether they are maskable or nonmaskable, the distinctions shown in Table 5-7 define categories of exceptions that the processor core handles uniquely. Note that Table 5-7 includes no synchronous imprecise instructions.

The processor core's exceptions, and conditions that cause them, are listed in Table 5-8.

Table 5-8. Exceptions and Conditions

Exception Type	Vector Offset (hex)	Causing Conditions
Reserved	00000	—
System reset	00100	A system reset is caused by the assertion of $\overline{\text{HRST\_CPU}}$, $\overline{\text{SRESET}}$ or $\overline{\text{sreset}}$ (asserted by the EPIC unit).
Machine check	00200	A machine check exception is caused by the assertion of the NMI input signal or the occurrence of internal errors as described in Chapter 13, "Error Handling." This exception occurs when a machine check condition is detected, the error is enabled, HID0[EMCP] is set, PICR1[MCP_EN] is set, and MSR[ME] is set. When one of these errors occurs, the MPC8240 takes the exception and asserts the $\overline{\text{MCP}}$ output signal.
DSI	00300	The cause of a DSI exception can be determined by the bit settings in the DSISR, listed as follows: 1 Set if the translation of an attempted access is not found in the primary hash table entry group (HTEG), in the rehashed secondary HTEG, or in the range of a DBAT register; otherwise cleared. 4 Set if a memory access is not permitted by the page or DBAT protection mechanism; otherwise cleared. 5 Set by an **eciwx** or **ecowx** instruction if the access is to an address that is marked as write-through or execution of a load/store instruction that accesses a direct-store segment. 6 Set for a store operation and cleared for a load operation. 11 Set if **eciwx** or **ecowx** is used and EAR[E] is cleared.
ISI	00400	An ISI exception is caused when an instruction fetch cannot be performed for any of the following reasons: • •The effective (logical) address cannot be translated. That is, there is a page fault for this portion of the translation, so an ISI exception must be taken to load the PTE (and possibly the page) into memory. • •The fetch access is to a direct-store segment (indicated by SRR1[3] set). • •The fetch access violates memory protection (indicated by SRR1[4] set). If the key bits (Ks and Kp) in the segment register and the PP bits in the PTE are set to prohibit read access, instructions cannot be fetched from this location.
External interrupt	00500	An external interrupt is caused when MSR[EE] = 1 and the internal $\overline{\text{int}}$ signal is asserted by the EPIC interrupt module to the processor core.

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Table 5-8. Exceptions and Conditions (Continued)

Exception Type	Vector Offset (hex)	Causing Conditions
Alignment	00600	An alignment exception is caused when the processor core cannot perform a memory access for any of the reasons described below: • •The operand of a floating-point load or store is to a direct-store segment. • •The operand of a floating-point load or store is not word-aligned. • •The operand of a **lmw**, **stmw**, **lwarx**, or **stwcx**. is not word-aligned. • •The operand of an elementary, multiple or string load or store crosses a segment boundary with a change to the direct store T bit. • •The operand of **dcbz** instruction is in memory that is write-through required • or caching inhibited, or **dcbz** is executed in an implementation that has either no data cache or a write-through data cache. • •A misaligned **eciwx** or **ecowx** instruction • •A multiple or string access with MSR[LE] set The processor core differs from MPC603e in that it initiates an alignment exception when it detects a misaligned **eciwx** or **ecowx** instruction and does not initiate an alignment exception when a little-endian access is misaligned.
Program	00700	A program exception is caused by one of the following exception conditions, which correspond to bit settings in SRR1 and arise during execution of an instruction: • •Illegal instruction—An illegal instruction program exception is generated when execution of an instruction is attempted with an illegal opcode or illegal combination of opcode and extended opcode fields (including PowerPC instructions not implemented in the processor core), or when execution of an optional instruction not provided in the processor core is attempted (these do not include those optional instructions that are treated as no-ops). • •Privileged instruction—A privileged instruction type program exception is generated when the execution of a privileged instruction is attempted and the MSR register user privilege bit, MSR[PR], is set. In the processor core, this exception is generated for **mtspr** or **mfspr** with an invalid SPR field if SPR[0] = 1 and MSR[PR] = 1. This may not be true for all PowerPC processors. • •Trap—A trap type program exception is generated when any of the conditions specified in a trap instruction are met.
Floating-point unavailable	00800	A floating-point unavailable exception is caused by an attempt to execute a floating-point instruction (including floating-point load, store, and move instructions) when the floating-point available bit is cleared (MSR[FP] = 0).
Decrementer	00900	The decrementer exception occurs when the most significant bit of the decrementer (DEC) register transitions from 0 to 1. Must also be enabled with the MSR[EE] bit.
Reserved	00A00–00BFF	—
System call	00C00	A system call exception occurs when a System Call (**sc**) instruction is executed.
Trace	00D00	A trace exception is taken when MSR[SE] = 1 or when the currently completing instruction is a branch and MSR[BE] = 1.
Floating-point assist	00E00	The MPC8420 does not generate an exception to this vector. Other PowerPC processors may use this vector for floating-point assist exceptions.
Reserved	00E10–00FFF	—
Instruction translation miss	01000	An instruction translation miss exception is caused when the effective address for an instruction fetch cannot be translated by the ITLB.
Data load translation miss	01100	A data load translation miss exception is caused when the effective address for a data load operation cannot be translated by the DTLB.

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Table 5-8. Exceptions and Conditions (Continued)

Exception Type	Vector Offset (hex)	Causing Conditions
Data store translation miss	01200	A data store translation miss exception is caused when the effective address for a data store operation cannot be translated by the DTLB, or when a DTLB hit occurs, and the changed bit in the PTE must be set due to a data store operation.
Instruction address breakpoint	01300	An instruction address breakpoint exception occurs when the address (bits 0–29) in the IABR matches the next instruction to complete in the completion unit, and the IABR enable bit (bit 30) is set.
System management interrupt	01400	A system management interrupt is caused when MSR[EE] = 1 and the $\overline{\text{SMI}}$ input signal is asserted.
Reserved	01500–02FFF	—

5.5.3 Exception Priorities

The exception priorities for the processor core are unchanged from those described in the *MPC603e User's Manual* except for the alignment exception, whose causes are prioritized as follows:

1. Floating-point operand not word-aligned
2. **lmw**, **stmw**, **lwarx**, or **stwcx** operand not word-aligned
3. **eciwx** or **ecowx** operand misaligned
4. A multiple or string access is attempted with MSR[LE] set.

Also, there is a priority mechanism for all the conditions specific to the MPC8240 that can cause a machine check exception. These are described in Chapter 13, "Error Handling."

5.6 Memory Management

The following subsections describe the memory management features of the PowerPC architecture and the MPC8240 implementation.

5.6.1 PowerPC MMU Model

The primary functions of the MMU are:

- to translate logical (effective) addresses to physical addresses for memory accesses
- to provide access protection on blocks and pages of memory

There are two types of accesses generated by the processor core that require address translation—instruction accesses and data accesses to memory generated by load and store instructions.

The PowerPC MMU and exception models support demand-paged virtual memory. Virtual memory management permits execution of programs larger than the size of physical

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memory; demand-paged implies that individual pages are loaded into physical memory from system memory only when they are first accessed by an executing program.

The PowerPC architecture supports the following three translation methods:

- Address translations disabled. Translation is enabled by setting bits in the MSR—MSR[IR] enables instruction address translations and MSR[DR] enables data address translations. Clearing these bits disables translation and the effective address is used as the physical address.
- Block address translation. The PowerPC architecture defines independent four-entry BAT arrays for instructions and data that maintain address translations for blocks of memory. Block sizes range from 128 Kbyte to 256 Mbyte and are software selectable. The BAT arrays are maintained by system software. The BAT registers, defined by the PowerPC architecture for block address translations, are shown in Figure 5-2.
- Demand page mode. The page table contains a number of page table entry groups (PTEGs). A PTEG contains eight page table entries (PTEs) of eight bytes each; therefore, each PTEG is 64 bytes long. PTEG addresses are entry points for table search operations.

  The hashed page table is a variable-sized data structure that defines the mapping between virtual page numbers and physical page numbers. The page table size is a power of 2; its starting address is a multiple of its size.

  On-chip instruction and data TLBs provide address translation in parallel with the on-chip cache access, incurring no additional time penalty in the event of a TLB hit. A TLB is a cache of the most recently used page table entries. Software is responsible for maintaining the consistency of the TLB with memory. In the MPC8240, the processor core's TLBs are 64-entry, two-way set-associative caches that contain instruction and data address translations. The MPC8240's core provides hardware assist for software table search operations through the hashed page table on TLB misses. Supervisor software can invalidate TLB entries selectively.

The MMU also directs the address translation and enforces the protection hierarchy programmed by the operating system in relation to the supervisor/user privilege level of the access and in relation to whether the access is a load or store.

5.6.2 MPC8240 Implementation-Specific MMU Features

The instruction and data MMUs in the processor core provide 4 Gbytes of logical address space accessible to supervisor and user programs with a 4-Kbyte page size and 256-Mbyte segment size.

The MPC8240 MMUs support up to 4 Petabytes (2^{52}) of virtual memory and 4 Gbytes (2^{32}) of physical memory (referred to as real memory in the PowerPC architecture specification) for instructions and data. Referenced and changed status is maintained by the processor for each page to assist implementation of a demand-paged virtual memory system.

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The MPC8240 TLBs are 64-entry, two-way set-associative caches that contain instruction and data address translations. The processor core provides hardware assist for software table search operations through the hashed page table on TLB misses. Supervisor software can invalidate TLB entries selectively.

After an effective address is generated, the higher-order bits of the effective address are translated by the appropriate MMU into physical address bits. Simultaneously, the lower-order address bits (that are untranslated; therefore, considered both logical and physical), are directed to the on-chip caches where they form the index into the four-way set-associative tag array. After translating the address, the MMU passes the higher-order bits of the physical address to the cache, and the cache lookup completes. For caching-inhibited accesses or accesses that miss in the cache, the untranslated lower-order address bits are concatenated with the translated higher-order address bits; the resulting 32-bit physical address is then used by the system interface, which accesses external memory.

For instruction accesses, the MMU performs an address lookup in both the 64 entries of the ITLB, and in the IBAT array. If an effective address hits in both the ITLB and the IBAT array, the IBAT array translation takes priority. Data accesses cause a lookup in the DTLB and DBAT array for the physical address translation. In most cases, the physical address translation resides in one of the TLBs and the physical address bits are readily available to the on-chip cache.

When the physical address translation misses in the TLBs, the processor core provides hardware assistance for software to search the translation tables in memory. When a required TLB entry is not found in the appropriate TLB, the processor vectors to one of the three TLB miss exception handlers so that the software can perform a table search operation and load the TLB. When this occurs, the processor automatically saves information about the access and the executing context. Refer to the *MPC603e User's Manual* for more detailed information about these features and the suggested software routines for searching the page tables.

5.7 Instruction Timing

The processor core is a pipelined superscalar processor. A pipelined processor is one in which the processing of an instruction is broken into discrete stages. Because the processing of an instruction is broken into a series of stages, an instruction does not require the entire resources of an execution unit at one time. For example, after an instruction completes the decode stage, it can pass on to the next stage, while the subsequent instruction can advance into the decode stage. This improves the throughput of the instruction flow. The instruction pipeline in the processor core has four major stages, described as follows:

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- The fetch pipeline stage primarily involves retrieving instructions from the memory system and determining the location of the next instruction fetch. Additionally, the BPU decodes branches during the fetch stage and folds out branch instructions before the dispatch stage if possible.
- The dispatch pipeline stage is responsible for decoding the instructions supplied by the instruction fetch stage, and determining which of the instructions are eligible to be dispatched in the current cycle. In addition, the source operands of the instructions are read from the appropriate register file and dispatched with the instruction to the execute pipeline stage. At the end of the dispatch pipeline stage, the dispatched instructions and their operands are latched by the appropriate execution unit.
- During the execute pipeline stage, each execution unit that has an executable instruction executes the selected instruction (perhaps over multiple cycles), writes the instruction's result into the appropriate rename register, and notifies the completion stage that the instruction has finished execution. In the case of an internal exception, the execution unit reports the exception to the completion/writeback pipeline stage and discontinues instruction execution until the exception is handled. The exception is not signaled until that instruction is the next to be completed. Execution of most load/store instructions is also pipelined. The load/store unit has two pipeline stages. The first stage is for effective address calculation and MMU translation, and the second stage is for accessing the data in the cache.
- The complete/writeback pipeline stage maintains the correct architectural machine state and transfers the contents of the rename registers to the GPRs and FPRs as instructions are retired. If the completion logic detects an instruction causing an exception, all following instructions are cancelled, their execution results in rename registers are discarded, and instructions are fetched from the correct instruction stream.

The processor core provides support for single-cycle store operations and provides an adder/comparator in the SRU that allows the dispatch and execution of multiple integer add and compare instructions on each cycle.

Performance of integer divide operations has been improved in the processor core. Execution of a divide instruction takes half the cycles to execute than that described in the MPC603e User's Manual. The new latency is reflected in Table 5-9.

Table 5-9. Integer Divide Latency

Primary Opcode	Extended Opcode	Mnemonic	Form	Unit	Cycles
31	459	**divwu**[**o**][**.**]	xo	IU	20
31	491	**divw**[**o**][**.**]	xo	IU	20

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5.8 Differences between the MPC8240 Core and the PowerPC 603e Microprocessor

The MPC8240 processor core is a derivative of the MPC603e microprocessor design. Some changes have been made and are visible either to a programmer or a system designer. Any software designed for an MPC603e is functional when replaced with the MPC8240 except for the specific customer-visible changes listed in Table 5-10.

Software can distinguish between the MPC603e and the MPC8240 by reading the processor version register (PVR). The MPC8240's processor version number is 0x0081; the processor revision level starts at 0x0100 and is incremented for each revision of the chip. It is expected that this information is most useful for programmers writing data cache flush routines.

Table 5-10. Major Differences between MPC8240's Core and the MPC603e User's Manual

Description	Impact
Changed HID1 to add bus frequency multipliers as described in the MPC8240 Hardware Specification	On extra bit is provided for PLL configuration, and some other unused encodings of the PLL_CFG[0–4] are now defined.
Added hardware support for misaligned little endian accesses	Except for strings/multiples, little-endian load/store accesses not on a word boundary generate exceptions under the same circumstances as big-endian accesses.
Removed misalignment support for **eciwx** and **ecowx** instructions.	These instructions cause an alignment exception if the operands are not on a word boundary.
Removed HID0[5]; now reserved	There is no support for ICE pipeline tracking.
Removed HID0[7]; now reserved	No impact, as the MPC8240 has no $\overline{\text{ARTRY}}$ signal.
Added instruction and data cache locking mechanism	Implements a cache way locking mechanism for both the instruction and data caches. One to three of the four ways in the cache can be locked with control bits in the HID2 register. See Section 5.3.1.2.3, "Hardware Implementation-Dependent Register 2 (HID2)."
Improved access to cache during block fills	The MPC8240 provides quicker access to incoming data and instruction on a cache block fill. See Section 5.4.2, "MPC8240 Implementation-Specific Cache Implementation."
Improved integer divide latency	Performance of integer divide operations has been improved in the processor core. A divide takes half the cycles to execute as described in MPC603e User's Manual. The new latency is reflected in Table 5-9.
No support for **dcbz** instruction in areas of memory that are write-through and can be accessed by multiple logical addresses	This was previously documented as an anomaly in the MPC603e. Stores of zeros must be used instead of the **dcbz** instruction when the memory area is designated as write-through, coherency required.

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Table 5-10. Major Differences between MPC8240's Core and the MPC603e User's Manual (Continued)

Description	Impact
Areas of memory accessed by **dcbz** instruction should not be marked as global	This was previously documented as an anomaly in the MPC603e. Areas of memory accessed by a **dcbz** instruction must be marked as not global in the BAT or PTE.
All edits described in the MPC603e & EC603e Microprocessor User's Manual Errata document	For example, Note that incoherency may occur if a write-through store is followed by a **dcbz** instruction that is in turn followed by a snoop, all to the same cache block. This occurs when the logical address for the **dcbz** and the write-through store are different but aliased to the same physical page. To avoid potential adverse effects, **dcbz** should not be used to zero cache blocks in memory marked as write-through that can be accessed through multiple logical addresses. Explicit store instructions with data of zeroes should be used instead. Note that broadcasting a sequence of **dcbz** instructions may cause snoop accesses to be retried indefinitely, which may cause the snoop originator to time out or may cause the snooped transaction to not complete. This can be avoided by disabling the broadcasting of **dcbz** by marking the memory space being addressed by the **dcbz** instruction as not global in the BAT or PTE. Also, Add the following text after the first paragraph of the sub-bullet for Floating-point registers (FPRs): Before the **stfd** instruction is used to store the contents of an FPR to memory, the FPR must have been initialized after reset (explicitly loaded with any value) by using a floating point load instruction. These are just a few examples. Refer to the errata document for a complete list.

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Chapter 6
MPC8240 Memory Interface

The MPC8240 integrates a high-performance memory controller that controls processor and PCI interactions to local memory. The MPC8240 supports various types of DRAM and ROM/Flash configurations as local memory.

- SDRAM
  - — SDRAMs must comply with the JEDEC specification for SDRAM
  - — High-bandwidth bus (32- or 64-bit data bus) to SDRAM
  - — One-Mbyte to 1-Gbyte SDRAM memory—1 to 8 chip selects for SDRAM bank sizes ranging from 1 Mbyte to 128 Mbytes per bank
  - — Supports page mode SDRAMs—four open pages simultaneously
  - — Programmable timing for SDRAMs
- DRAM—fast page mode (FPM) and extended data out (EDO)
  - — High-bandwidth bus (32- or 64-bit data bus) to DRAM
  - — One-Mbyte to 1-Gbyte DRAM memory space
  - — One to eight chip selects of 4-, 16-, 64- or 128-Mbit memory devices
  - — Programmable timing for FPM and EDO
- ROM/Flash
  - — 16 Mbytes of ROM/Flash space can be divided between the PCI bus and the memory bus (8 Mbytes each)
  - — Supports 8-bit asynchronous ROM or 64-bit burst-mode ROM
  - — Configurable data path—8-, 32-, or 64-bit
  - — Supports bus-width writes to Flash
- Port X—The ROM/Flash controller can interface any device that can be controlled with an address and data field (communication devices, DSPs, general purpose I/O devices, or registers). Some devices may require a small amount of external logic to properly generate address strobes and chip selects.
  - — 8-bit Port X
  - — 32-bit Port X
  - — 64-bit Port X—the floating-point (FPU) unit must be enabled for 64-bit writes

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- Data path buffering—72 bits (64-bit data and 8-bit parity)
  - — Reduces loading on the internal processor core bus
  - — Reduces loading of the drivers of the memory system
  - — Reduces signal trace delay known as time-of-flight (TOF)
- Parity—Supports normal parity and read-modify-write (RMW)
- Error checking and correction (ECC)—64-bit only
  - — DRAM ECC—Located in the central control unit (CCU)
  - — SDRAM ECC—Located in-line with the data path buffers

The MPC8240 is designed to control a 32- or 64-bit data path to main memory (SDRAM or DRAM). The MPC8240 can be configured to check parity or ECC on memory reads. Parity checking and generation can be enabled with 4 parity bits for a 32-bit data path or 8 parity bits for 64-bit data path. Concurrent ECC is only generated for 64-bit data path with 8 syndrome bits.

The MPC8240 supports SDRAM or DRAM bank sizes from 1 to 128 Mbytes and provides bank start address and end address configuration registers. However the MPC8240 does not support mixed SDRAM or DRAM configurations.

The MPC8240 can be configured so that appropriate row and column address multiplexing occurs for each physical bank. Addresses (DRAM or SDRAM) and bank selects (SDRAM only) are provided through a 14-bit interface for SDRAM and 13-bit interface for DRAM.

ROM/Flash systems are supported by up to 21 address bits, 2 bank selects, 1 write enable and 1 output enable. Figure 6-1 is a block diagram of the memory interface.

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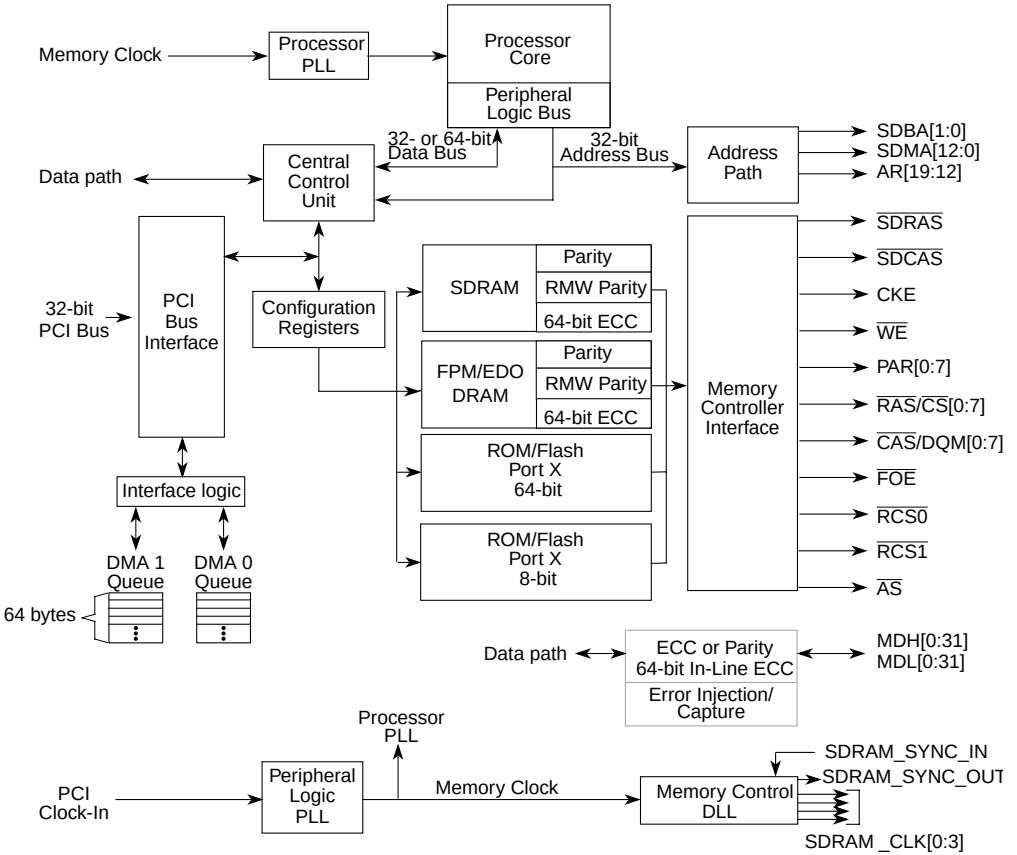

Figure 6-1. Block Diagram for Memory Interface

6.1 Memory Interface Signal Summary

Table 6-1 summarizes the memory interface signals. Note that some signals function differently depending on the type of memory system the MPC8240 is configured to support.

Table 6-1. Memory Interface Signal Summary

Signal Name	Signal Name	Alternate Function	Pins	I/O
$\overline{\text{RAS}}$[0:7]	DRAM row address strobe 0–7	$\overline{\text{CS}}$[0:7]	8	O
$\overline{\text{CAS}}$[0:7]	DRAM column address strobe 0–7	DQM[0:7]	8	O
$\overline{\text{CS}}$[0:7]	SDRAM chip select 0–7	$\overline{\text{RAS}}$[0:7]	8	O
DQM[0:7]	SDRAM data mask in/out 0–7	$\overline{\text{CAS}}$[0:7]	8	O
$\overline{\text{WE}}$	Write enable	—	1	O

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Table 6-1. Memory Interface Signal Summary (Continued)

Signal Name	Signal Name	Alternate Function	Pins	I/O
SDMA[12:0]	SDRAM address 12–0	See Table 6-2, "Memory Address Signal Mappings"	13	O
SDBA[1:0]	SDRAM bank select 1–0		2	O
MDH[0:31]	Data bus high	—	32	I/O
MDL[0:31] MDL[0][1]	Data bus low	—	32	I/O
PAR[0:7]	Data parity 0–7	AR[19:12]	8	I/O
AR[19:12]	ROM address 19–12	PAR[0:7]	8	O
CKE[1]	SDRAM clock enable	—	1	O
$\overline{\text{SDRAS}}$	SDRAM row address strobe	—	1	O
$\overline{\text{SDCAS}}$	SDRAM column address strobe	—	1	O
$\overline{\text{RCS0}}$[1]	ROM or bank 0 select	—	1	O
$\overline{\text{RCS1}}$	ROM or bank 1select	—	1	O
$\overline{\text{FOE}}$[1]	Flash output enable	—	1	O
$\overline{\text{AS}}$[1]	Address strobe for Port X	—	1	O

[1] The MPC8240 samples these signals at the negation of $\overline{\text{HRST\_CTRL}}$ to determine the reset configuration. After they are sampled, they assume their normal functions. See Section 2.4, "Configuration Signals Sampled at Reset," for more information about their function during reset.

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Table 6-2 shows memory address signal mappings.

Table 6-2. Memory Address Signal Mappings

MPC8240 Signal Name (Outputs)		Logical Names					JEDEC DIMM Signals (Inputs)	
		FPM/ EDO DRAM Address	2-bank SDRAM Address	4-bank SDRAM Address	ROM/ Flash Address 8- and 32-bit mode	ROM/ Flash Address 64-bit mode	SDRAM 168-pin DIMM	FPM/ EDO 168-pin DIMM
msb	SDMA12/ SDBA1	MA12	SDMA12	SDBA1	AR20	–	BA1	A12
	PAR0				AR19	AR19		
	PAR1				AR18	AR18		
	PAR2				AR17	AR17		
	PAR3				AR16	AR16		
	PAR4				AR15	AR15		
	PAR5				AR14	AR14		
	PAR6				AR13	AR13		
	PAR7				AR12	AR12		
	SDBA0	MA11	SDBA0	SDBA0	AR11	AR11	BA0	A11
	SDMA11	–	SDMA11	SDMA11	–	–	A11	–
	SDMA10	MA10	SDMA10	SDMA10	AR10	AR10	A10(AP)	A10
	SDMA9	MA9	SDMA9	SDMA9	AR9	AR9	A9	A9
	SDMA8	MA8	SDMA8	SDMA8	AR8	AR8	A8	A8
	SDMA7	MA7	SDMA7	SDMA7	AR7	AR7	A7	A7
	SDMA6	MA6	SDMA6	SDMA6	AR6	AR6	A6	A6
	SDMA5	MA5	SDMA5	SDMA5	AR5	AR5	A5	A5
	SDMA4	MA4	SDMA4	SDMA4	AR4	AR4	A4	A4
	SDMA3	MA3	SDMA3	SDMA3	AR3	AR3	A3	A3
	SDMA2	MA2	SDMA2	SDMA2	AR2	AR2	A2	A2
	SDMA1	MA1	SDMA1	SDMA1	AR1	AR1	A1	A1
lsb	SDMA0	MA0	SDMA0	SDMA0	AR0	AR0	A0	A0

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6.2 SDRAM Interface Operation

Figure 6-2 shows an internal block diagram of the SDRAM interface of the MPC8240.

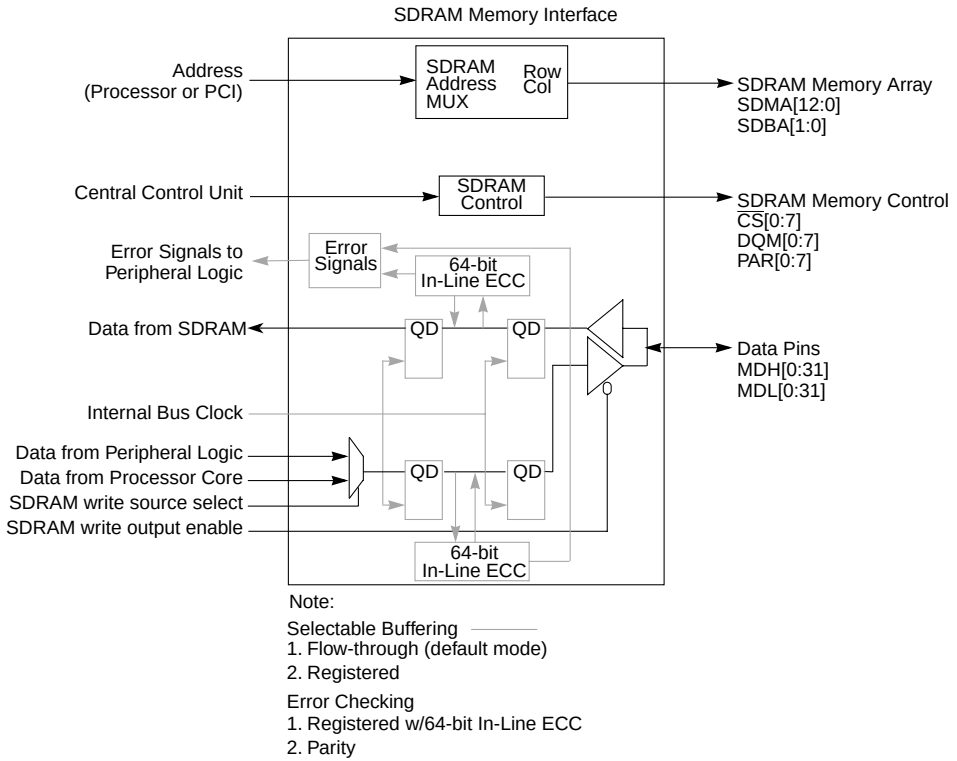

Figure 6-2. SDRAM Memory Interface Block Diagram

The MPC8240 provides control functions and signals for JEDEC-compliant SDRAM. The MPC8240 supplies the SDRAM_CLK[0:3] to be distributed to the SDRAM. These clocks are the same frequency and in phase with the memory bus clock.

The SDRAM memory bus can be configured to be 64 bits (72 bits with parity) requiring a four-beat SDRAM data burst, or configured to be 32 bits (36 bits with parity) requiring an eight-beat SDRAM data burst.

Twelve row/column multiplexed address signals (SDMA[11:0]) and two bank select signals (SDBA[1:0]) provide SDRAM addressing for up to 16 M. The data width of the device determines its density and the physical bank size. Eight chip select signals ($\overline{\text{CS}}$[0:7]) support up to eight banks of memory. Eight SDRAM data in/out mask signals (DQM[0:7]) provide byte selection for 32- and 64-bit accesses. Thus, an 8-bit SDRAM device has a DQM signal and eight data signals (DQ[0:7]). A 16-bit SDRAM device has two DQM signals associated to specific halves of the sixteen data signals (DQ[0:7] and DQ[8:15]).

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Table 6-3 shows the MPC8240's relationships between data byte lane 0–7, DQM[0:7], and MDH[0:31] and MDL[0:31] for 32- and 64-bit modes.

Table 6-3. SDRAM Data Bus Lane Assignments

Data Byte Lane	Data In/Out Mask	Data Bus 32-bit Mode	Data Bus 64-bit Mode
$0_{(MSB)}$	DQM[0]	MDH[0:7]	MDH[0:7]
1	DQM[1]	MDH[8:15]	MDH[8:15]
2	DQM[2]	MDH[16:23]	MDH[16:23]
3	DQM[3]	MDH[24:31]	MDH[24:31]
4	DQM[4]	—	MDL[0:7]
5	DQM[5]	—	MDL[8:15]
6	DQM[6]	—	MDL[16:23]
$7_{(LSB)}$	DQM[7]	—	MDL[24:31]

In addition, there are sixty four data signals (MDH[0:31] and MDL[0:31]), a write enable signal ($\overline{WE}$), a row address strobe signal ($\overline{SDRAS}$), a column address strobe signal ($\overline{SDCAS}$), a memory clock enable signal (CKE), and eight bidirectional data parity signals (PAR[0:7]). Note that the banks can be built of x1, x4, x8, x16, or x32 SDRAMs as they become available.

Collectively, these interface signals allow a total of 1 Gbyte addressable memory. Programmable $\overline{CAS}$ latency is supported for data read operations. For write operations, the first beat of write data is supplied concurrent with the write command. The memory design must be byte-selectable for writes using the MPC8240's DQM outputs.

The MPC8240 allows four simultaneous open pages for page mode; the number of clocks for which the pages are maintained open is programmable by the BSTOPRE and PGMAX parameters. Page register allocation uses a least recently used (LRU) algorithm.

An example SDRAM configuration, with 8 banks, is shown in Figure 6-3. The SDRAM configuration is an eight-bank, 512-Mbyte SDRAM memory array with a 72-bit data bus. Each bank is comprised of nine 8 Mbits x 8 SDRAMs. One of the nine 8 Mbits x 8 SDRAMs is used for the bank's parity checking function. Certain address and control lines may or may not require buffering, depending upon the system design. Analysis of the MPC8240 AC specifications, desired memory operating frequency, capacitive loads, and board routing loads can assist the system designer in deciding whether any signals require buffering. See the *MPC8240 Hardware Specifications* for more information.

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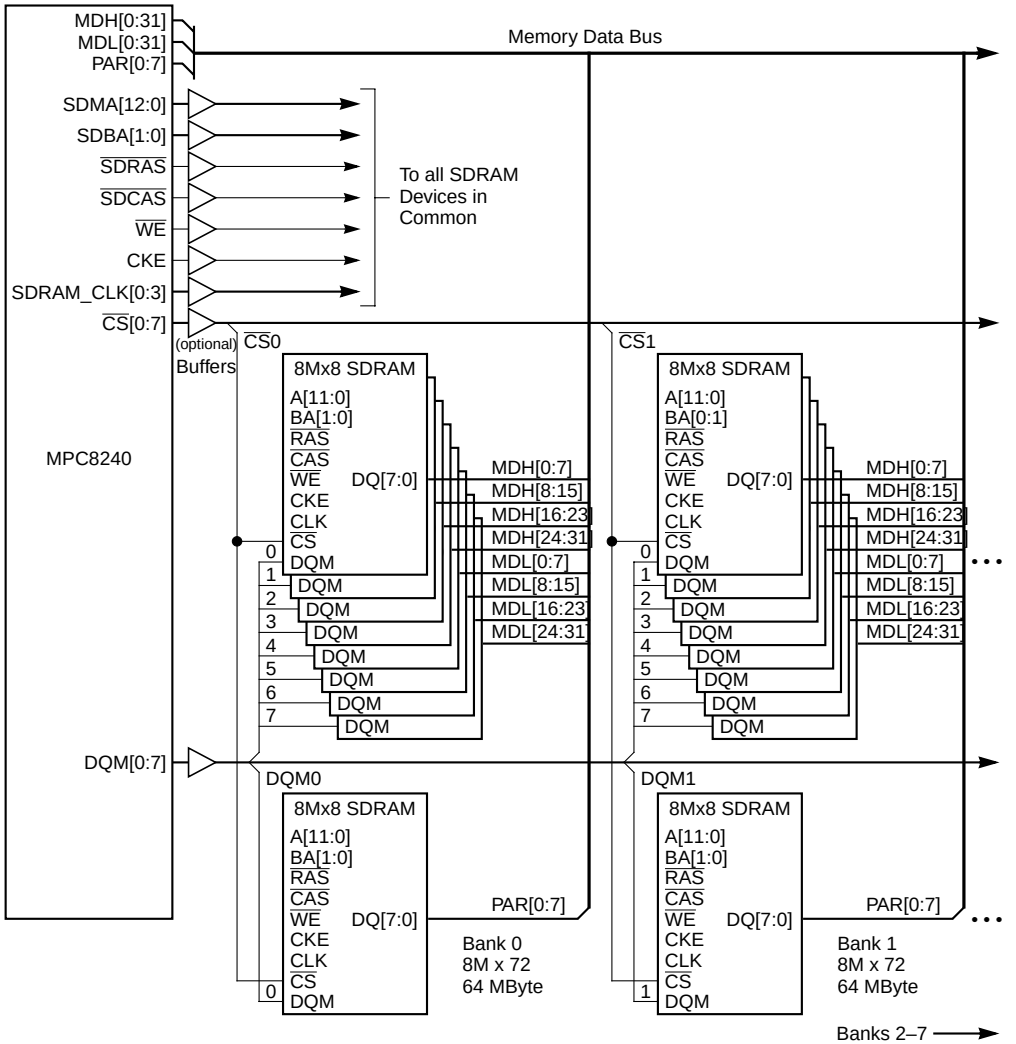

NOTES:
1. All signals are connected in common (in parallel) except for $\overline{CS}$[0:7], SDRAM_CLK[0:3], the DQM signals used for parity, and the data bus lines
2. Optional parit memories may use any DQM signal. To minimize loading, a different DQM line is recommended for each bank: DQMO for Bank 0, DQM1 for Bank 1, etc.
3. Each of the $\overline{CS}$[0:7] signals correspond with a separate physical bank of memory; $\overline{CS}$0 for the first bank, etc.
4. Buffering may be needed if large memory arrays are used.
5. SDRAM_CLK[0:3] signals may be apportioned among all memory devices.

Figure 6-3. Example 512-MByte SDRAM Configuration With Parity

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6.2.1 Supported SDRAM Organizations

It is not necessary to use identical memory chips in each memory bank; individual memory banks may be of differing size. Although the MPC8240 multiplexes the row address, column address, and logical bank select bits onto a shared 14-bit memory address bus, individual SDRAM banks may be implemented with memory devices requiring fewer than 28 address bits. The MPC8240 can be configured to provide 12- or 11-row bits to a particular bank, and 10, 9, 8, or 7 column bits, and 2 or 4 logical banks.

System software must configure the MPC8240 for the correct memory bank sizes. A memory polling algorithm can be used at start-up to determine start and end of memory. Alternately, many DIMMs have an on-board serial-presence-detect (SPD) EEPROM that contains information about the size and timing requirements of the SDRAMs on the DIMM. A software routine can use the I^2C to read the SPD. Boot firmware can initially set the SDRAM timing parameters with conservative values. Later, when the I^2C routine reads the SPD information from the DIMM, the timing parameters can be adjusted accordingly.

The MPC8240 uses its bank map to assert the appropriate $\overline{CS}$[0:7] signal for memory accesses according to the provided bank depths. System software must also configure the MPC8240 at system start-up to appropriately multiplex the row and column address bits for each bank. Refer to the row-address configuration in MCCR1. Address multiplexing occurs according to these configuration bits.

If a disabled bank has its starting and ending address defined as overlapping an enabled bank's address space, there may be system memory corruption in the overlapping address range. Any unused banks should have their starting and ending addresses programmed out of the range of memory banks in use.

Table 6-4 shows the unsupported multiplexed row and column address bits for 32- and 64-bit modes. Configurations using 7 or 8 column address bits in 32-bit data bus mode and 7 column bits in 64-bit data bus mode are not supported as they would create non-contiguous address spaces.

Table 6-4. Unsupported Multiplexed Row and Column Address Bits

32-bit Data Bus Mode	64-bit Data Bus Mode
13x8	—
12x8	—
11x8	—
12x7	12x7

Table 6-5 summarizes the SDRAM memory configurations supported by the MPC8240. Note that Table 6-5 is not an exhaustive list of all configurations that the MPC8240 can support. The MPC8240 can support any device that can accept the address multiplexing described in Section 6.2.2, "SDRAM Address Multiplexing," without exceeding the 1 Gbyte limit on physical memory.

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Table 6-5. Supported SDRAM Device Configurations

SDRAM Device Density	Device Organization	Addressing—Row Bits x Column Bits x Logical Banks[1]	MCCR1 [Bank *n* row] setting	Number of Devices in a Physical Bank[2,3]	Physical Bank Size[3,4] (Mbytes)
16 Mbit (2 banks)	4M x 4 bits	13 x 8 x 2[5]	0b01	16	32
		11 x 10 x 2	0b11		
	2M x 8 (or 9) bits	11 x 9 x 2	0b11	8	16
	1M x 16 (or 18) bits	11 x 8 x 2[5]	0b11	4	8
64 Mbit (2 banks)	16M x 4 bits	13 x 10 x 2	0b01	16	128
	8M x 8 (or 9) bits	13 x 9 x 2	0b01	8	64
	4M x 16 (or 18) bits	13 x 8 x 2[5]	0b01	4	32
64 Mbit (4 banks)	16M x 4 bits	12 x 10 x 4	0b00	16	128
	8M x 8 (or 9) bits	12 x 9 x 4	0b00	8	64
	4M x 16 (or 18) bits	12 x 8 x 4[5]	0b00	4	32
	2M x 32 (or 36) bits	11 x 8 x 4[5]	0b00	2	16
128 Mbit (2 Banks)	16M x 8 (or 9) bits	13 x 10 x 2	0b01	8	128
	8M x 16 (or 18) bits	13 x 9 x 2	0b01	4	64
	4M x 32 (or 36) bits	13 x 8 x 2[5]	0b01	2	32
128 Mbit (4 Banks)	16M x 8 (or 9) bits	12 x 10 x 4	0b00	8	128
	8M x 16 (or 18) bits	12 x 9 x 4	0b00	4	64
	4M x 32 (or 36) bits	12 x 8 x 4[5]	0b00	2	32
256 Mbit (4 banks)	16M x 16 (or 18) bits	12 x 10 x 4	0b00	4	128

1 A logical bank is defined for the MPC8240 as a portion of memory addressed through an SDRAM bank select.

2 A physical bank is defined for the MPC8240 as a portion of memory addressed through an SDRAM chip select. Certain modules of SDRAM may have two physical banks and require two chip selects to be programmed to support a single module.

3 Number of devices and size for physical banks are based on a 64-bit data bus, for a 32-bit data bus these values would be halved.

4 The physical bank size is the amount of memory addressed by a single SDRAM chip select.

5 Not supported for 32-bit data bus

6.2.2 SDRAM Address Multiplexing

This section describes how the MPC8240 translates processor addresses into SDRAM memory addresses.

The MPC8240 SDRAM memory address signals SDMA[12:0] are labeled with SDMA12 as the most-significant bit (msb) and SDMA0 as the least-significant bit (lsb). Most SDRAM devices are labeled with A0 as the least significant address input. Therefore, the MPC8240 SDMA[12:0] signals should be connected to SDRAM devices according to Table 6-2.

Table 6-6 shows the multiplexing of the internal physical addresses $A[0_{msb}:31_{lsb}]$ through SDBA[1:0] and SDMA[12:0] during the row and column phases when operating in 32-bit mode.

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Table 6-6. SDRAM Address Multiplexing SDBA[1:0] and SDMA[12:0]—32-Bit Mode

Row x Col x Bank		msb Physical Address lsb																															
		0-4					5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
11x10x2	SDRAS										BA0	10	9	8	7	6	5	4	3	2	1	0											
	SDCAS									9	BA0												8	7	6	5	4	3	2	1	0		
11x9x2	SDRAS										BA0	10	9	8	7	6	5	4	3	2	1	0											
	SDCAS										BA0												8	7	6	5	4	3	2	1	0		
13x10x2	SDRAS								11	12	BA0	10	9	8	7	6	5	4	3	2	1	0											
	SDCAS							9			BA0												8	7	6	5	4	3	2	1	0		
13x9x2	SDRAS								12	11	BA0	10	9	8	7	6	5	4	3	2	1	0											
	SDCAS										BA0												8	7	6	5	4	3	2	1	0		
12x10x4	SDRAS								11	BA1	BA0	10	9	8	7	6	5	4	3	2	1	0											
	SDCAS							9		BA1	BA0												8	7	6	5	4	3	2	1	0		
12x9x4	SDRAS								11	BA1	BA0	10	9	8	7	6	5	4	3	2	1	0											
	SDCAS									BA1	BA0												8	7	6	5	4	3	2	1	0		

Table 6-7 shows the multiplexing of the internal physical addresses $A[0_{msb}:1_{lsb}]$ through SDBA[1:0] and SDMA[12:0] during the row and column phases of the 64-bit mode. The shaded cells in Figure 6-7 are the unspecified bits.

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Table 6-7. SDRAM Address Multiplexing SDBA[1:0] and SDMA[12:0]—64-Bit Mode

Row x Col x Bank		Physical Address (msb → lsb)																																
		0-2			3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
11x10x2	SDRAS										BA0	10	9	8	7	6	5	4	3	2	1	0												
	SDCAS								9	8	BA0												7	6	5	4	3	2	1	0			
11x9x2	SDRAS										BA0	10	9	8	7	6	5	4	3	2	1	0												
	SDCAS									8	BA0												7	6	5	4	3	2	1	0			
11x8x2	SDRAS										BA0	10	9	8	7	6	5	4	3	2	1	0												
	SDCAS										BA0												7	6	5	4	3	2	1	0			
13x10x2	SDRAS								11	12	BA0	10	9	8	7	6	5	4	3	2	1	0												
	SDCAS						9	8			BA0												7	6	5	4	3	2	1	0			
13x9x2	SDRAS								11	12	BA0	10	9	8	7	6	5	4	3	2	1	0												
	SDCAS							8			BA0												7	6	5	4	3	2	1	0			
13x8x2	SDRAS								11	12	BA0	10	9	8	7	6	5	4	3	2	1	0												
	SDCAS										BA0												7	6	5	4	3	2	1	0			
12x10x4	SDRAS								11	BA1	BA0	10	9	8	7	6	5	4	3	2	1	0												
	SDCAS						9	8		BA1	BA0												7	6	5	4	3	2	1	0			
12x9x4	SDRAS								11	BA1	BA0	10	9	8	7	6	5	4	3	2	1	0												
	SDCAS							8		BA1	BA0												7	6	5	4	3	2	1	0			

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Table 6-7. SDRAM Address Multiplexing SDBA[1:0] and SDMA[12:0]—64-Bit Mode (Continued)

Row x Col x Bank		msb Physical Address lsb																													
		0-2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
11x8x4 or 12x8x4	SDRAS						11	BA1	BA0	10	9	8	7	6	5	4	3	2	1	0											
	SDCAS							BA1	BA0												7	6	5	4	3	2	1	0			

6.2.3 SDRAM Memory Data Interface

To reduce loading on the data bus, the MPC8240 features on-chip buffers between the internal processor core data bus and the memory data bus. The MPC8240 supports three types of internal data path buffering for the SDRAM data interface—flow-through, registered, and in-line buffer mode. Flow-through buffer mode is the default mode for the MPC8240.

Table 6-8 lists the parameters that determine the data path buffer mode and also control the parity or ECC operation of the MPC8240.

Table 6-8. Memory Data Path Parameters

Bit Name	Register and Offset	Bit Number in Register
RAM_TYPE	MCCR1 @F0	17
EDO	MCCR2 @F4	16
PCKEN	MCCR1 @F0	16
WRITE _PARITY_CHK	MCCR2 @F4	19
INLINE_RD_EN	MCCR2 @F4	18
INLINE_PAR_NOT_ECC	MCCR2 @F4	20
BUF_TYPE[0]	MCCR4 @FC	22
BUF_TYPE[1]	MCCR4 @FC	20
RMW_PAR	MCCR2 @F4	0
ECC_EN	MCCR2 @F4	17
MEM_PARITY_ECC_EN	ErrEnR1 @C0	2
MB_ECC_ERR_EN	ErrEnR2 @C4	3

Table 6-9 describes the parameter settings for the available SDRAM data path buffer options. Note that configuration register bit settings that are not specified in Table 6-9 have undefined behavior.

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Table 6-9. SDRAM System Configurations

RAM_TYPE	EDO	PCKEN	WRITE_PARITY_CHK	INLRD_PARECC _CHK_EN	INLINE_PAR_NOT_ECC	BUF_TYPE[0]	BUF_TYPE[1]	RMW_PAR	ECC_EN	MEM_PARITY_ECC_EN	MB_ECC_ERR_EN	Description
0	0	0	0	0	0	0	0	0	0	0	0	Ffow-through, no ECC or parity
0	0	0	0	0	0	0	1	0	0	0	0	Registered, no ECC or parity
0	0	1	0	0	0	0	0	0	0	1	0	Flow- through parity
0	0	1	0	0	0	0	1	0	0	1	0	Registered buffer parity
0	0	1	0	0	0	0	0	1	0	1	0	Flow- through RMW parity
0	0	1	0	0	0	0	1	1	0	1	0	Registered buffer RMW parity
0	0	0	0	0	0	1	0	0	0	0	0	In-line, no parity
0	0	0	1	1	1	1	0	0	0	1	0	In-line, parity enabled
0	0	0	1	1	1	1	0	1	0	1	0	In-line, RMW parity enabled
0	0	0	1	1	0	1	0	1	0	1	1	In-line, ECC enabled

The data path between the internal processor core bus and the external memory bus for flow-through buffer mode is shown in Figure 6-4.

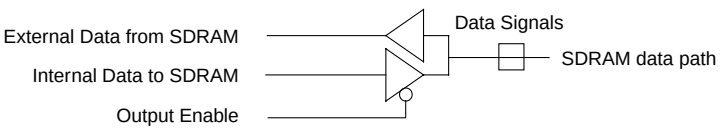

Figure 6-4. SDRAM Flow-Through Memory Interface

The registered buffer mode interface is shown in Figure 6-5. The registered buffer mode allows a higher memory interface frequency at the expense of a clock cycle of latency on SDRAM reads.

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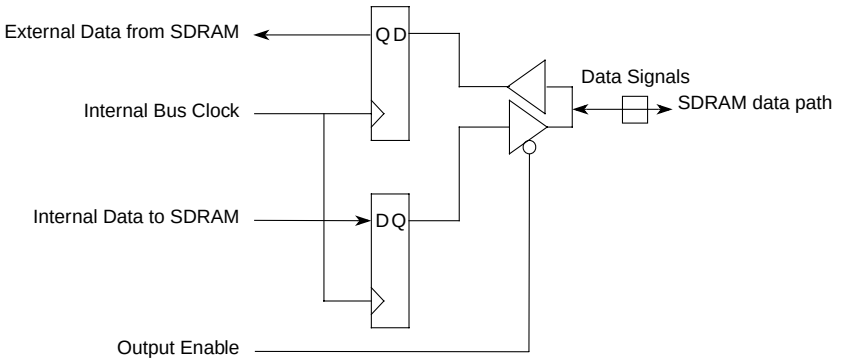

Figure 6-5. SDRAM Registered Memory Interface

The in-line buffer mode interface is shown in Figure 6-6. In-line buffer mode allows for ECC or parity generation and checking between the internal processor core bus and the external SDRAM data bus. In-line ECC is described in Section 6.2.10, “SDRAM In-Line ECC.”

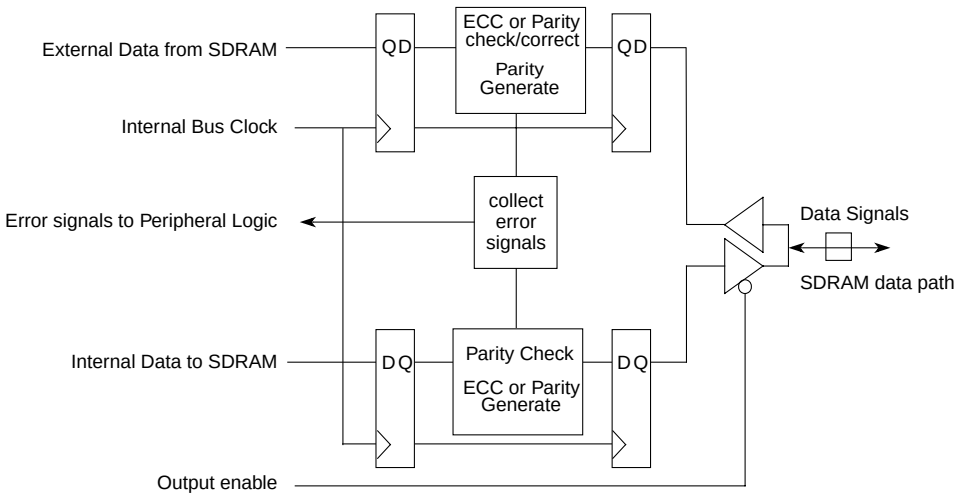

Figure 6-6. SDRAM In-line ECC/Parity Memory Interface

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6.2.4 SDRAM Power-On Initialization

At system reset, initialization software must set up the programmable parameters in the memory interface configuration registers. These include the memory boundary registers, the memory banks enable register, the memory page mode register, and the memory control configuration registers (MCCRs). See Chapter 4, “Configuration Registers,” for more detailed descriptions of the configuration registers. The programmable parameters relevant to the SDRAM interface are:

- Memory bank starting and ending addresses (memory boundary registers)
- Memory bank enables
- PGMAX—maximum activate to precharge interval (also called row active time or t_{RAS})
- SREN—self refresh enable
- RAM_TYPE—SDRAM, FPM or EDO
- PCKEN—parity check enable
- Row address configuration for each bank
- INLINE_PAR_NOT_ECC select between ECC or parity on the memory bus for in-line buffer mode only.
- WRITE_PARITY_CHK—enable write path parity error reporting
- INLRD_PARECC_CHK_EN—enable in-line read path ECC or parity error reporting
- REFINT—interval between refreshes
- RSV_PG—reserves a page register, thus allowing only three simultaneously open pages
- RMW_PAR—enables read-modify-write parity operation
- BSTOPRE—burst to precharge interval (page open interval)
- REFREC—refresh recovery interval from last refresh clock cycle to activate command
- RDLAT—data latency from read command
- PRETOACT—precharge to activate interval
- ACTOPRE—activate to precharge interval
- BUF_TYPE—selects the data path buffer mode (flow-through, registered, in-line)
- REGDIMM—enables registered DIMM mode
- SDMODE—mode register data to be transferred to SDRAM array by the MPC8240—specifies CAS latency, wrap type, and burst length
- ACTORW—activate to read or write interval

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After configuration of all parameters is complete, system software must set the MCCR1[MEMGO] bit to enable the memory interface. The MPC8240 then conducts an initialization sequence to prepare the SDRAM array for accesses. The initialization sequence for JEDEC compliant SDRAM is as follows:

- Precharge all internal banks of the SDRAM device.
- Issue 8 refresh commands.
- Issue mode register set command to initialize the mode register.

When the sequence completes, the SDRAM array is ready for access.

6.2.5 MPC8240 Interface Functionality for JEDEC SDRAMs

All read or write accesses to SDRAM are performed by the MPC8240 using various combinations of the JEDEC standard SDRAM interface commands. SDRAM samples command and data inputs on rising edges of the memory clock. Additionally, SDRAM output data must be sampled on rising edges of the memory clock. Table 6-10 describes the MPC8240 SDRAM interface command and data inputs.

The following SDRAM interface commands are provided by the MPC8240.

- Bank Activate—Latches row address and initiates memory read of that row. Row data is latched in SDRAM sense amplifiers and must be restored by a precharge command before another bank activate is done.
- Precharge—Restores data from the sense amplifiers to the appropriate row. Also initializes the sense amplifiers in preparation for reading another row in the memory array, (performing another activate command). Precharge must be performed if the row address will change on next access.
- Read—Latches column address and transfers data from the selected sense amplifier to the output buffer as determined by the column address. During each succeeding clock, additional data will be output without additional read commands. The amount of data so transferred is determined by the burst size.
- Write—Latches column address and transfers data from the data pins to the selected sense amplifier as determined by the column address. During each succeeding clock, additional data is transferred to the sense amplifiers from the data pins without additional write commands. The amount of data so transferred is determined by the burst size. Sub-burst write operations are controlled with DQM[0:7].
- Refresh (similar to CAS before RAS)—Causes a row to be read in both memory banks (JEDEC SDRAM) as determined by the refresh row address counter. This refresh row address counter is internal to the SDRAM. After being read, the row is automatically rewritten in the memory array. Before execution of refresh, all memory banks must be in a precharged state.

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- Mode register set (for configuration)—Allows setting of SDRAM options. These options are CAS latency, burst type, and burst length.
  - — CAS latency may be chosen as provided by the preferred SDRAM. (Some SDRAMs provide CAS latency 1, 2, 3, some provide CAS latency 1, 2, 3, 4).
  - — Burst type must be set to sequential.
  - — Although some SDRAMs provide variable burst lengths of 1, 2, 4, 8 page size, the MPC8240 supports only a burst length of 4 or 8. Burst length 4 must be selected for operation with a 64 bit memory interface and 8-beat burst lengths are used with a 32-bit memory interface. Burst lengths of 1 and 2 page size are not supported by the MPC8240. This command is performed by the MPC8240 during system initialization.

    The mode register data (CAS latency, burst length and burst type), is provided by software at reset in the MPC8240 configuration register and is subsequently transferred to the SDRAM array by the MPC8240after MEMGO is enabled.
- Self refresh (for long periods of standby)—Used when the device will be in standby for very long periods of time. Automatically generates internal refresh cycles to keep the data in both memory banks refreshed. Before execution of this command, all memory banks must be in a precharged state.

Table 6-10. MPC8240 SDRAM Interface Commands

Command	$\overline{\text{SDRAS}}$	$\overline{\text{SDCAS}}$	$\overline{\text{WE}}$	$\overline{\text{CS}}$	CKE
Bank activate	Asserted	Negated	Negated	Asserted	Asserted
Precharge	Asserted	Negated	Asserted	Asserted	Asserted
Read	Negated	Asserted	Negated	Asserted	Asserted
Write	Negated	Asserted	Asserted	Asserted	Asserted
CBR refresh	Asserted	Asserted	Negated	Asserted	Asserted
Mode register set	Asserted	Asserted	Asserted	Asserted	Asserted
Self refresh	Asserted	Asserted	Negated	Asserted	Negated

The MPC8240 automatically issues a precharge command to the SDRAM when the BSTOPRE or PGMAX intervals have expired, regardless of pending memory transactions from the PCI bus orprocessorcore. See Section 6.2.7, “SDRAM Page Mode,” for more information about the BSTOPRE and PGMAX parameters. The MPC8240 can perform precharge cycles concurrent with snoop broadcasts for PCI transactions.

6.2.6 SDRAM Burst and Single-Beat Transactions

In 64-bit data bus mode, the MPC8240 performs a four-beat burst for every transaction (burst and single-beat); in 32-bit data bus mode, the MPC8240 performs an eight-beat burst for every transaction (burst and single-beat). The burst is always sequential, and the critical double word is always supplied first. For example, in 64-bit data bus mode, if the processor core requests the third double word of a cache block, the MPC8240 reads double words

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from memory in the order 2-3-0-1. In 32-bit data bus mode, if the processor core requests the third double word of a cache block, the MPC8240 reads words from memory in the order 4-5-6-7-0-1-2-3.

For single-beat read transactions, the MPC8240 masks the extraneous data in the burst by driving the DQM[0:7] signals high on the irrelevant cycles. For single-beat write transactions, the MPC8240 protects non-targeted addresses by driving the DQM[0:7] signals high on the irrelevant cycles. For single-beat transactions, the bursts cannot be terminated early. That is, if the relevant data is in the first data phase, the subsequent data phases of the burst must run to completion even though the data is irrelevant.

6.2.7 SDRAM Page Mode

Under certain conditions, the MPC8240 retains four active SDRAM pages for burst or single-beat accesses. These conditions are as follows:

- A pending transaction (read or write) hits one of the currently active internal pages.
- There are no pending refreshes.
- The burst-to-precharge interval (controlled by BSTOPRE[0:9]) has not been exceeded.
- The maximum activate-to-precharge interval (controlled by PGMAX) has not been exceeded.
- MCCR2[RSV_PG] = 0b0. In this case only three active pages are allowed.

Note that the BSTOPRE[0:9] parameter is composed of BSTOPRE[0:1] (bits 19–18 of MCCR4), BSTOPRE[2:5] (bits 31–28 of MCCR3), and BSTOPRE[6:9] (bits 3–0 of MCCR4).

Page mode can dramatically reduce access latencies for page hits. Depending on the memory system design and timing parameters, using page mode can save clock cycles from subsequent burst accesses that hit in an active page. SDRAM page mode is controlled by the BSTOPRE[0:9], and PGMAX parameters. Page mode is disabled by clearing the PGMAX or BSTOPRE[0:9] parameters.

The page open duration counter is loaded with BSTOPRE[0:9] every time the page is accessed (including page hits). When the counter expires (or when PGMAX expires) the open page is closed with a precharge bank command. Page hits can occur at any time in the interval specified by BSTOPRE.

The 1-byte memory page mode register (MPMR) contains the PGMAX parameter that controls how long the MPC8240 retains the currently accessed page (row) in memory. The PGMAX parameter specifies the activate-to-precharge interval (sometimes called row active time or t_{RAS}). The PGMAX value is multiplied by 64 to generate the actual number of clock cycles for the interval. When PGMAX is programmed to 0x00, page mode is disabled.

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The value for PGMAX depends on the specific SDRAM devices used, the ROM system, and the operating frequency of the MPC8240. When the interval specified by PGMAX expires, the MPC8240 must close the active page by issuing a precharge bank command. PGMAX must be sufficiently less than the maximum row active time for the SDRAM device to ensure that the issuing of a precharge command is not stalled by a memory access. When PGMAX expires during a memory access, the MPC8240must wait for the access to complete before issuing the precharge command to the SDRAM. In the worst case, the MPC8240 initiates a memory access one clock cycle before PGMAX expires. If ROM is located on the memory bus, the longest access that could potentially stall a precharge is a burst read from ROM. If ROM is located on the PCI bus, the longest memory access is a burst read from the SDRAM.

The MPC8240 also requires two clock cycles to issue a precharge bank command to the SDRAM device so the PGMAX interval must be further reduced by two clock cycles. Therefore, PGMAX should be programmed according to the following equation:

PGMAX < [$t_{RAS(MAX)}$ – (worst case memory access) – 2] / 64

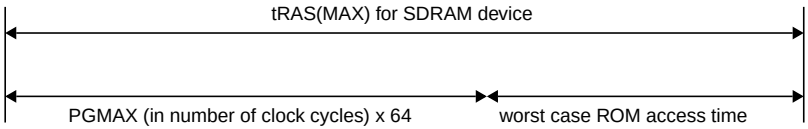

Figure 6-7. PGMAX Parameter Setting for SDRAM Interface

For example, consider a system with a memory bus clock frequency of 66 MHz using SDRAMs with a maximum row active time ($t_{RAS(MAX)}$) of 100 us. The maximum number of clock cycles between activate bank and precharge bank commands is 66 MHz x 100 us = 6600 clock cycles.

If the system uses 8-bit ROMs on the memory bus, a processor burst read (a 32-byte cache line read) from ROM (a non-bursting ROM device) follows the timing shown in Figure 6-60. Also affecting the ROM access time is MCCR2[TS_WAIT_TIMER]. The minimum time allowed for ROM devices to enter high impedance is two clock cycles. TS_WAIT_TIMER adds clocks (n–1) to the minimum disable time. This delay is enforced after all ROM accesses preventing any other memory access from starting. Therefore a burst read from an 8-bit ROM (worst case access time (wcat)) takes:

{[(ROMFAL + 2) x 8 + 3] x 4} + [2 + (TS_WAIT_TIMER – 1)] clock cycles

So, if MCCR1[ROMFAL] = 4 and MCCR2[TS_WAIT_TIMER] = 3, the interval for a local processor burst read from an 8-bit ROM takes

{[(4 + 2) x 8 + 3] x 4} + [2 + (3 – 1)] = 204 + 4 = 208 clock cycles.

Plugging the values into the PGMAX equation above,

PGMAX < (6600 – 213 – 2) ÷ 64 = 99.8 clock cycles.

The value stored in PGMAX would be 0b0110_0011 (or 99 clock cycles).

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6.2.7.1 SDRAM Paging in Sleep Mode

Systems attempting to go to sleep with SDRAM paging enabled must ensure that the following sequence of events occurs in software before the processor core enters sleep mode:

- Disable page mode by writing 0x00 to MPMR[PGMAX].
- Wait for any open pages to close by allowing a SDRAM refresh interval to elapse; MCCR[REFINT], bits (15:2)
- Processor core enters sleep mode.

Upon waking from sleep, software must perform the following sequence to re-enable paging (if so desired).

- Awake from sleep
- Enable page mode by writing the appropriate maximum page open interval based upon the system design to MPMR[PGMAX] (optional).

6.2.8 SDRAM Interface Timing

To accommodate available memory technology across a wide spectrum of operating frequencies, the MPC8240 allows the following SDRAM interface timing intervals to be programmable with granularity of 1 memory clock cycle:

- RDLAT—internal processor core bus data latency from read command
- REFREC—refresh command to activate command interval
- ACTORW—activate command to read or write command interval
- ACTOPRE—activate command to precharge command interval
- PRETOACT—precharge command to activate command interval
- BSTOPRE—burst to precharge command interval (page open interval)

The SDRAM interface timing intervals are defined in Table 6-11.

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Table 6-11. SDRAM Interface Timing Intervals

Timing Intervals	Definition		
RDLAT	The number of clock cycles from the read column command until the first data beat is available on the internal processor core data bus. RDLAT = SDRAM CAS latency + buffer mode delay + delay due to REGDIMM value. The value of RDLAT should be additionally increased by one if MCCR3[REGDIMM] = 1.		
	RDLAT Mode	MCCR3[REGDIMM]	
		0	1
	Flow through	CL	–
	Registered	CL + 1	CL + 2
	In-line ECC	CL + 2	CL + 3
REFREC	The number of clock cycles from the refresh command until an activate command is allowed. This can be calculated by referring to the AC specification of the SDRAM device. The AC specification indicates a minimum refresh to activate interval in nanoseconds.		
ACTORW	The number of clock cycles from an activate command until a read or write command is allowed. This interval will be listed (nS) in the AC specifications of the user's SDRAM.		
ACTOPRE	The number of clock cycles from an activate command until a precharge command is allowed. This interval will be listed (nS) in the AC specifications of the user's SDRAM.		
PRETOACT	The number of clock cycles from a precharge command until an activate command is allowed. This interval will be listed (nS) in the AC specifications of the user's SDRAM.		
BSTOPRE	The number of clock cycles to maintain a page open after an access. A subsequent access can generate a page hit during this interval. A page hit reloads the BSTOPRE counter. When the interval expires, a precharge is issued to the page.		

The value of the above six parameters, (in whole clock cycles) must be set by boot code at system start-up and kept in the MPC8240 configuration register space.

The following figures show SDRAM timing for various types of accesses. Figure 6-8 shows a single-beat read operation.

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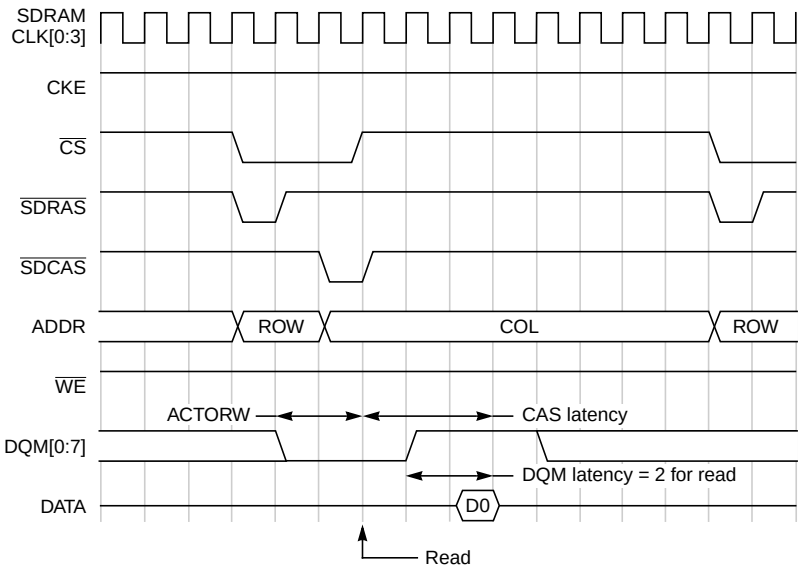

Figure 6-8. SDRAM Single-Beat Read Timing (SDRAM Burst Length = 4)

Figure 6-9 shows a four-beat burst read operation.

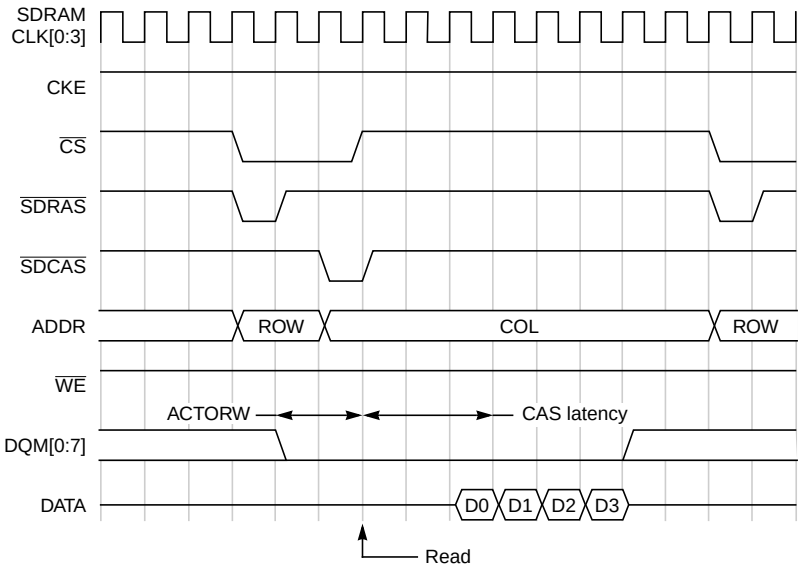

Figure 6-9. SDRAM Four-Beat Burst Read Timing Configuration—64-Bit Mode

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Figure 6-10 shows an eight-beat burst read operation.

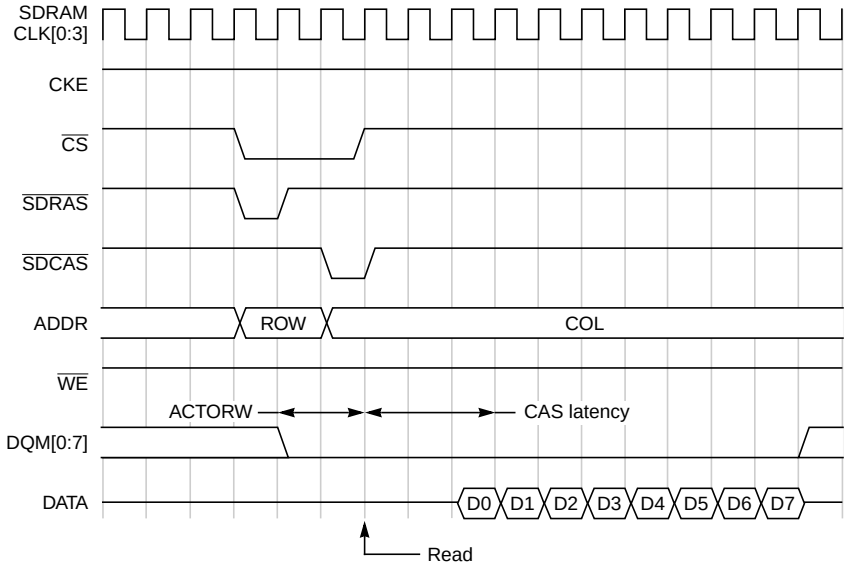

Figure 6-10. SDRAM Eight-Beat Burst Read Timing Configuration—32-Bit Mode

Figure 6-11 shows a single-beat write operation.

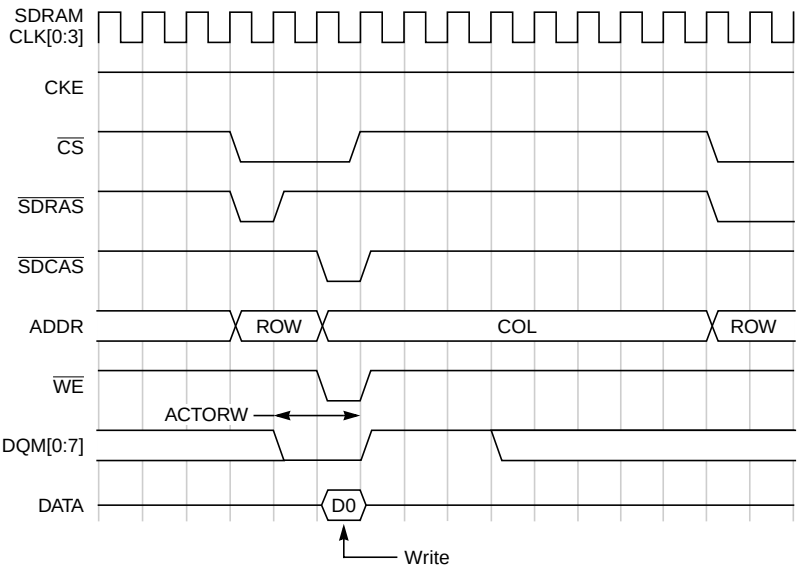

Figure 6-11. SDRAM Single Beat Write Timing (SDRAM Burst Length = 4)

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Figure 6-12 shows a four-beat burst-write operation.

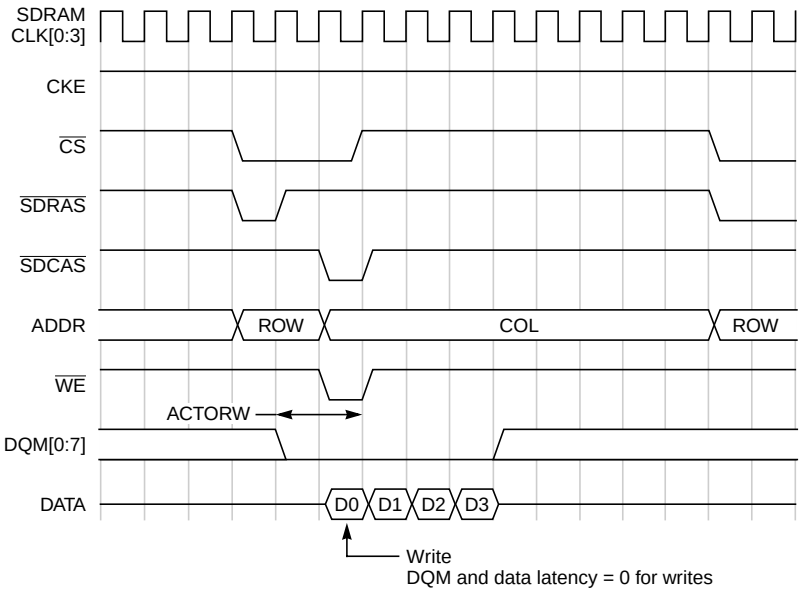

Figure 6-12. SDRAM Four-Beat Burst Write Timing—64-Bit Mode

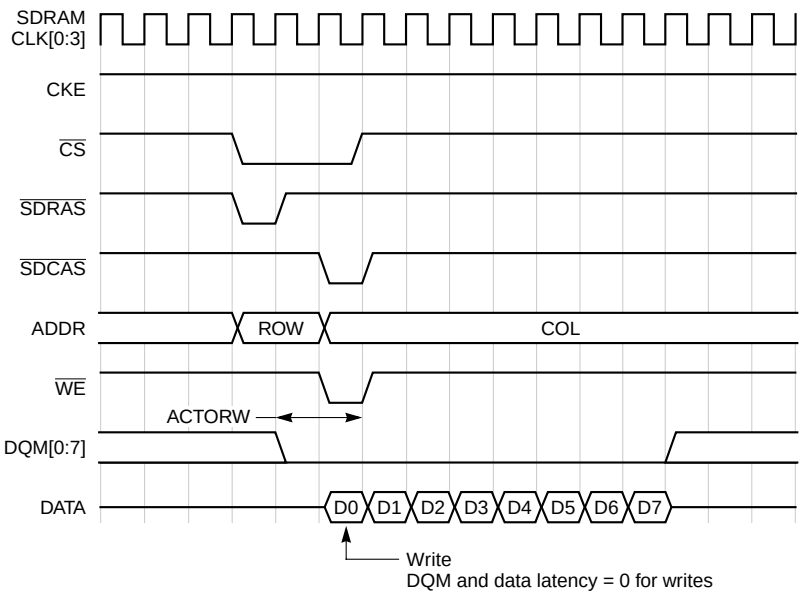

Figure 6-13. SDRAM Eight-Beat Burst Write Timing—32-Bit Mode

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6.2.8.1 SDRAM Mode-Set Command Timing

The MPC8240 transfers the mode register data, (CAS latency, burst length, and burst type) stored in MCCR4[SDMODE] to the SDRAM array by issuing the mode-set command when MCCR1[MEMGO] is set. The timing of the mode-set command is shown in Figure 6-14.

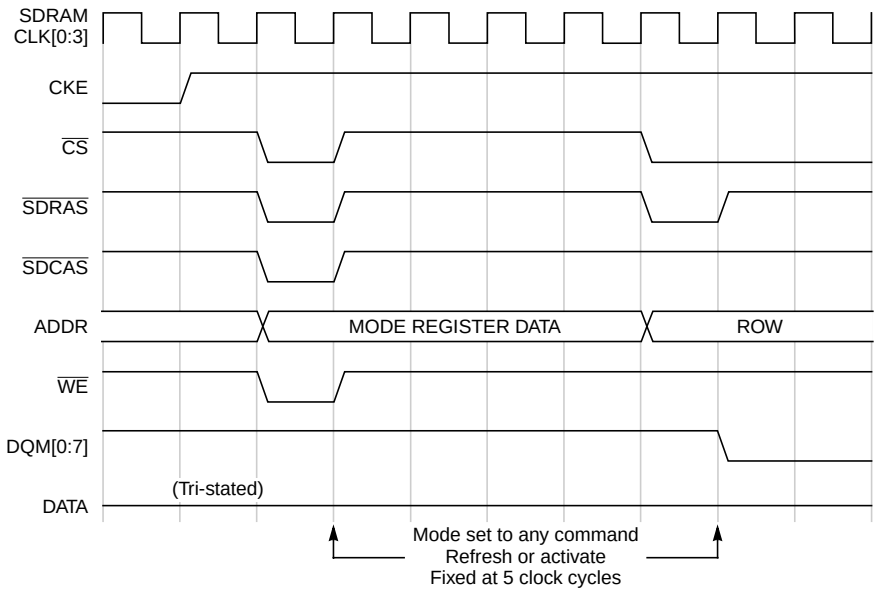

Figure 6-14. SDRAM Mode Register Set Timing

6.2.9 SDRAM Parity and RMW Parity

When configured for SDRAM, the MPC8240 supports two forms of parity checking and generation—normal parity and read-modify-write (RMW) parity. Normal parity assumes that each of the eight parity bits is controlled by a separate DQM signal. Thus, for a single-beat write to system memory, the MPC8240 generates a parity bit for each byte written to memory.

RMW parity assumes that all eight parity bits are controlled by a single DQM signal; therefore, all parity bits must be written as a single 8-bit quantity (byte). For any system memory write operations smaller than a double word, the MPC8240 must latch the write data, read a double word (64 bits), check the parity of that double word, merge it with the write data, regenerate parity for the new double word, and finally write the new double word back to memory.

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The MPC8240 checks parity on all memory reads, provided parity checking is enabled (PCKEN = 1). The MPC8240 generates parity for the following operations:

- PCI to memory write operations
- Processor core single-beat write operations with RMW parity enabled (RMW_PAR = 1)

The processor core is expected to generate parity for all other memory write operations as the data goes directly to memory and does not pass through the MPC8240.

6.2.9.1 RMW Parity Latency Considerations

When RMW parity is enabled, the time required to read, modify, and write increases latency for both processor single-beat writes and PCI writes to system memory. All other transactions are unaffected and operate as in normal parity mode.

For processor core single-beat writes to system memory, the MPC8240 latches the data, reads a double word from system memory (checking parity), and then merges that double word with the write data from the processor. The MPC8240 then generates new parity bits for the merged double word and writes the data and parity to memory. The read-modify-write process adds six clock cycles to a single-beat write operation. If page mode retention is enabled (BSTOPRE > 0 and PGMAX > 0), the MPC8240 keeps the memory in page mode for the read-modify-write sequence. Because the processor drives all eight parity bits during burst writes to system memory, these transactions go directly to the SDRAMs with no performance penalty.

For PCI writes to system memory with RMW parity enabled, the MPC8240 latches the data in the internal PCI-to-system-memory-write buffer (PCMWB). If the PCI master writes complete double words to system memory, the MPC8240 generates the parity bits when the PCMWB is flushed to memory. However, if the PCI master writes 32-, 16-, or 8-bit data that cannot be gathered into a complete double word in the PCMWB, a read-modify-write operation is required. The MPC8240 performs a double-word read from system memory (checking parity), and then merges the write data from the PCI master with the data read from memory. The MPC8240 then generates new parity for the merged double word and writes the data and parity to memory. If page mode retention is enabled (BSTOPRE > 0 and PGMAX > 0), the MPC8240 keeps the memory in page mode for the read-modify-write sequence.

6.2.10 SDRAM In-Line ECC

As an alternative to simple parity, the MPC8240supports ECC for the data path between the MPC8240 and system memory. ECC not only allows the MPC8240 to detect errors in the memory data path but also to correct single-bit errors in the 64-bit data path. Note that ECC is not supported for systems using a 32-bit data bus. ECC requires a read-modify-write to perform sub-double word write operations.

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The in-line ECC and parity data path option allows the MPC8240 to detect and automatically correct single bit ECC errors; detect multiple bit ECC errors or parity errors with only one clock cycle penalty on CPU and PCI memory read operations; and generate parity for the internal processor data bus. For CPU and PCI memory write operations, parity can be checked automatically on the internal processor data bus and either ECC or parity generated for the memory bus. Table 6-8 and Table 6-9 describe the configuration requirements for this mode.

The in-line ECC logic in the MPC8240 detects and corrects all single-bit errors and detects all double-bit errors and all errors within a nibble. Other errors are not guaranteed to be detected or corrected. Multiple-bit errors are always reported if detected. However, when a single-bit error occurs, the value in the ECC single bit error counter register is compared to the ECC single bit error trigger register. If the values are not equal, no error is reported; if the values are equal, then an error is reported. Thus, the single-bit error registers may be programmed so that minor faults with memory are corrected and ignored, but a catastrophic memory failure generates an interrupt. See Section 4.8.1, “ECC Single-Bit Error Registers,” for more information on these registers.

The MPC8240 supports concurrent ECC for the memory data path and parity for the local processor data path. ECC and parity may be independently enabled or disabled. The eight signals used for ECC (PAR[0:7]) are also used for processor core parity. The MPC8240 checks ECC on 64-bit memory reads.

The syndrome equations for the ECC codes are shown in Table 6-12 and Table 6-13.

Table 6-12. The MPC8240 SDRAM ECC Syndrome Encoding (Data Bits 0:31)

Syndrome Bit	Data Bit																															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x				x				x				x
1	x				x				x				x				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2		x				x				x				x			x				x				x				x			
3			x				x				x				x			x				x				x				x		
4				x				x				x				x			x	x			x	x			x	x			x	x
5					x	x	x	x					x	x	x	x					x	x	x	x					x	x	x	x
6									x	x	x	x	x	x	x	x									x	x	x	x	x	x	x	x
7	x	x	x	x									x	x	x	x	x	x	x					x				x	x	x	x	

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Table 6-13. The MPC8240 SDRAM ECC Syndrome Encoding (Data Bits 32:63)

Syndrome Bit	Data Bit																															
	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
0			x				x				x				x					x				x				x		x		
1				x				x				x				x	x				x				x						x	
2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x				x				x						x
3	x				x				x				x						x				x				x		x	x	x	x
4		x	x	x		x	x	x		x	x	x		x	x	x													x	x	x	x
5					x	x	x	x					x	x	x	x	x	x	x	x	x	x	x	x								
6									x	x	x	x	x	x	x	x	x	x	x	x					x	x	x	x	x	x	x	x
7	x	x					x	x			x	x	x	x							x	x	x	x	x	x	x	x		x	x	x

6.2.11 SDRAM Registered DIMM Mode

The MPC8240 can be configured to support registered SDRAM DIMMs. To reduce loading, registered DIMMs latch the SDRAM control signals internally before using them to access the array. Enabling the MPC8240's registered DIMM mode (MCCR4 bit 15, REGDIMM = 1) compensates for this delay on the DIMMs control bus by delaying the MPC8240's data and parity buses for SDRAM writes by one additional clock cycle.

Enabling registered DIMM mode has no affect on the bus timing for SDRAM reads or ROM/Flash transfers. However, the programmed read latency (RDLAT) time for SDRAM reads must be incremented by one to compensate for the latch delay on the control signals of the registered DIMM. Figure 6-15 shows the registered SDRAM DIMM single-beat write timing.

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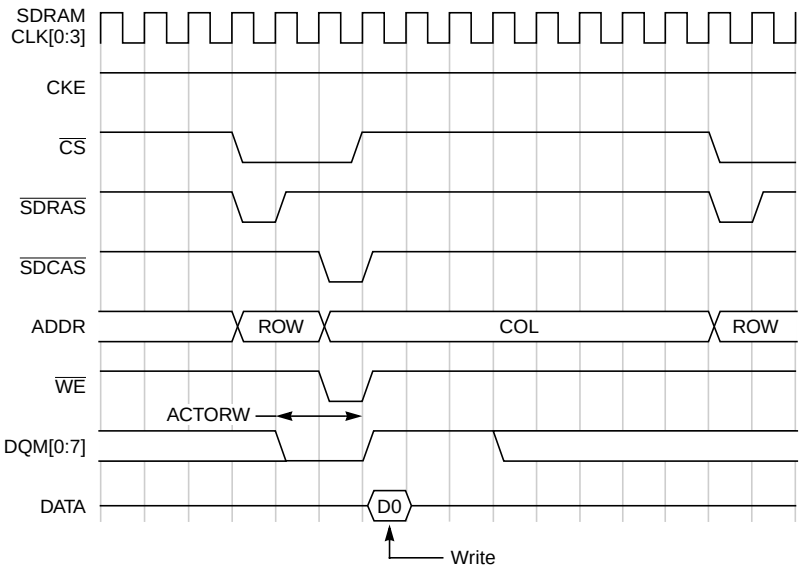

Figure 6-15. Registered SDRAM DIMM Single-Beat Write Timing

Figure 6-16 shows the registered SDRAM DIMM burst-write timing.

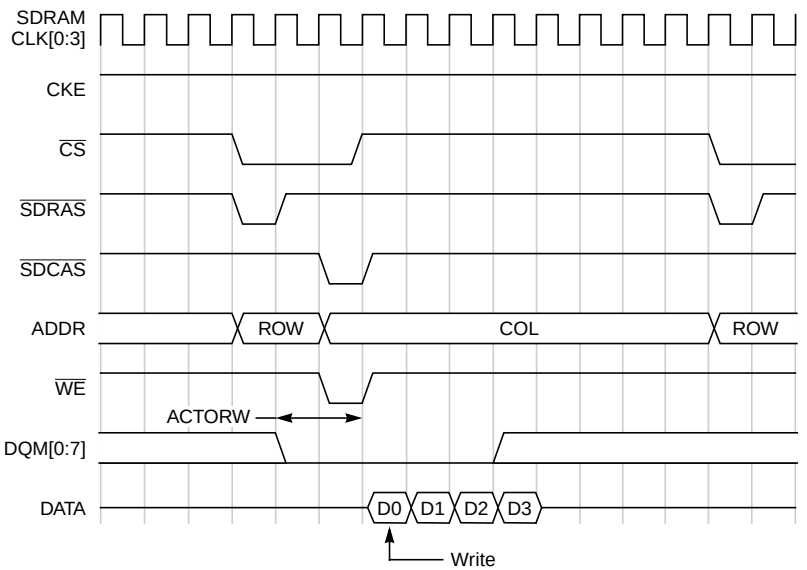

Figure 6-16. Registered SDRAM DIMM Burst-Write Timing

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6.2.12 SDRAM Refresh

The memory interface supplies CBR refreshes to SDRAM according to the interval specified in MCCR2[REFINT]. REFINT is the refresh interval. When REFINT expires and the memory bus is idle, the MPC8240 issues a precharge and then a refresh command to the SDRAM devices. However, if the memory bus is busy with a transaction, the refresh request is not performed and an internal, 4-bit, missed-refresh counter is incremented. The refresh interval timer is reset to the value in REFINT and the process begins again. When the refresh interval counter expires and the bus is idle, the MPC8240 performs all the missed refreshes back-to-back and the missed refresh counter is cleared. If the number of missed refreshes exceeds 16, the counter overflows and causes a refresh overflow error. See Section 13.3.2.4, "Memory Refresh Overflow Error," for more information about the reporting of these errors. In the worst case, the MPC8240 misses 16 refreshes and must perform all 16 refreshes. Figure 6-17 shows this worst case situation repeated over the device's refresh period.

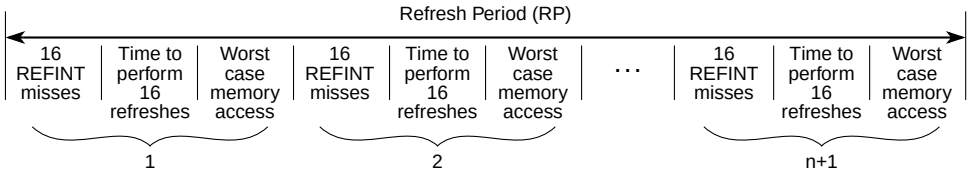

Figure 6-17. SDRAM Refresh Period

The value stored in REFINT must permit the MPC8240 to supply refreshes within the refresh period specified by the SDRAM device. Another factor in calculating the value for REFINT is the overhead for the MPC8240 to actually issue a refresh command to the SDRAM device. The MPC8240 has to precharge any open banks before it can issue the refresh command. The MPC8240 requires two clock cycles to issue a precharge to an internal bank; with the possibility of four banks open simultaneously, this equates to eight clock cycles. The MPC8240 must also wait for the PRETOACT interval to pass before issuing the refresh command. The refresh command itself takes four clock cycles (see Figure 6-18) with a dead cycle needed between subsequent refresh commands.

REFINT must also allow for a potential collision between memory accesses and refresh cycles. In the worst case, the refresh may have to wait the number of clock cycles required by the longest access. For example, if a local ROM access is in progress at the time a refresh operation needs to be performed, the refresh must wait until the ROM access has completed. If ROM is local, the longest access that could potentially stall a refresh is a burst read from ROM. If ROM is located on the PCI bus, the longest memory access is a burst read from the SDRAM.

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Therefore, REFINT should be programmed according to the following equation:

$$\text{REFINT} < \frac{\text{RP}}{(n+1)16} - \frac{16(\text{ROH})}{16} - \frac{\text{TWACC}}{16}$$

Where:

RP is the refresh period of the device = refresh period per bank x the number of banks x memory frequency

n = (the number of rows per bank x the number of banks per device) ÷ 16

ROH is the refresh overhead imposed by the MPC8240 and is composed of the precharge, the PRETOACT interval, the 4 clock cycles to issue the refresh command, and one dead cycle between refreshes.

TWACC is the worst case access time for the slowest device on the memory bus.

Consider a typical SDRAM device having two internal banks, 2K rows in each bank (4K rows total) with a refresh period of 32 ms for 2K rows. This means that the MPC8240 must refresh each internal bank (2K rows) every 32 ms. In this example there are two banks, so to refresh the whole SDRAM it takes 64 ms. If the memory bus operates at 66 MHz, RP = 64 ms x 66 MHz = 4224000 clock cycles to refresh all 4K rows. In this example *n* = 2048 x 2 ÷ 16 = 256. So, the value of the first term in the REFINT equation above is 4224000 ÷ [(256 + 1) x 16] = 1027.237

For this example, suppose PRETOACT is set to 2 clock cycles. In this case,
ROH = (2 x 2) + 2 + 4 + 1 = 11

If the system uses 8-bit ROMs on the local memory bus, a burst read from ROM will follow the timing shown in Figure 6-60. In addition, the minimum time allowed for ROM devices to enter high impedance is two clock cycles. This delay is enforced after all ROM accesses preventing any other memory access from starting. Therefore a burst read from an 8-bit ROM will take:

{[(ROMFAL + 2) x 8 + 3] x 4 + 5} + 2 clock cycles

So, if MCCR1[ROMFAL] = 4, the interval for a processor burst read from an 8-bit ROM will take:

{[(4 + 2) x 8 + 3] x 4 + 5} + 2 = 211 clock cycles

Plugging the values into the REFINT equation above:

REFINT < 1027.237 – 11 – (211÷16) = 1003 clock cycles (rounded down)

The value stored in REFINT would be 0b00_0011_1110_1011 (or 1003 clock cycles).

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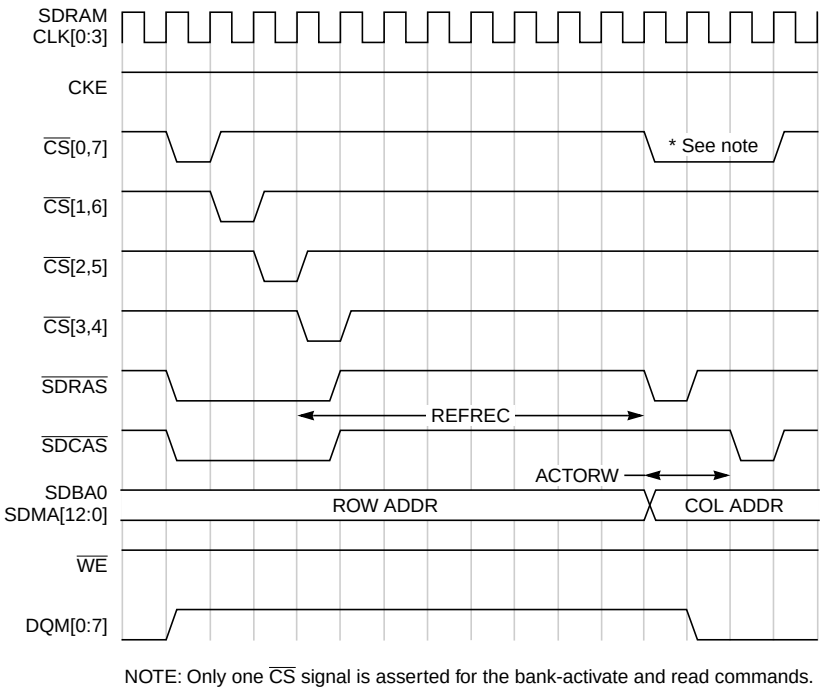
6.2.12.1 SDRAM Refresh Timing

The CBR refresh timing for SDRAM is controlled by the programmable timing parameter MCCR3[REFREC]. REFREC represents the number of clock cycles from the refresh command until a bank-activate command is allowed. The AC specifications of the specific SDRAM device provides a minimum refresh-to-activate interval.

The MPC8240 implements bank staggering for CBR refreshes, as shown in Figure 6-18. This reduces instantaneous current consumption for memory refresh operations.



NOTE: Only one $\overline{CS}$ signal is asserted for the bank-activate and read commands.

Figure 6-18. SDRAM Bank Staggered CBR Refresh Timing

6.2.12.2 SDRAM Refresh and Power Saving Modes

The MPC8240's memory interface provides for sleep, doze, and nap power saving modes defined for the local processor architecture. See Chapter 14, "Power Management," for more information on these modes.

In doze and nap power saving modes, the MPC8240 supplies normal CBR refresh to SDRAM. In sleep mode, the MPC8240 can be configured to use the SDRAM self-refresh mode, provide normal refresh to SDRAM, or provide no refresh support. If the MPC8240 is configured to provide no refresh support in sleep mode, system software is responsible for appropriately preserving SDRAM data, such as by copying to disk. Table 6-14 summarizes the MPC8240configuration bits relevant to power-saving modes.

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Table 6-15 summarizes the refresh types available in each power-saving modes and the relevant configuration parameters.

Table 6-14. SDRAM Controller Power Saving Configurations

Power Saving Mode	Power Save Configuration Bits And Signal Values	Refresh Type	Refresh Configuration Bit Settings
Sleep	PMCR1[PM] = 1 PMCR1[SLEEP] = 1	Self	PMCR1[LP_REF_EN] = 1, MEMCFG[SREN] = 1
		Normal	PMCR1[LP_REF_EN] = 1, MEMCFG[SREN] = 0
		None	PMCR1[LP_REF_EN] = 0
Nap	PMCR1[PM] = 1 PMCR1[SLEEP] = 0 PMCR1[NAP] = 1	Normal	No additional bits required
Doze	PMCR1[PM] = 1 PMCR1[SLEEP] = 0, PMCR1[NAP] = 0, PMCR1[DOZE] = 1	Normal	No additional bits required

Table 6-15. SDRAM Power Saving Modes Refresh Configuration

Power Saving Mode	Refresh Type	Power Management Control Register (PMCR1)					MCCR1 [SREN]
		PM	DOZE	NAP	SLEEP	LP_REF_EN	
Doze	Normal	1	1	0	0	—	—
Nap	Normal	1	—	1	0	—	—
Sleep	Self	1	—	—	1	1	1
	Normal	1	—	—	1	1	0

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The entry timing for self-refreshing SDRAMs is shown in Figure 6-19.

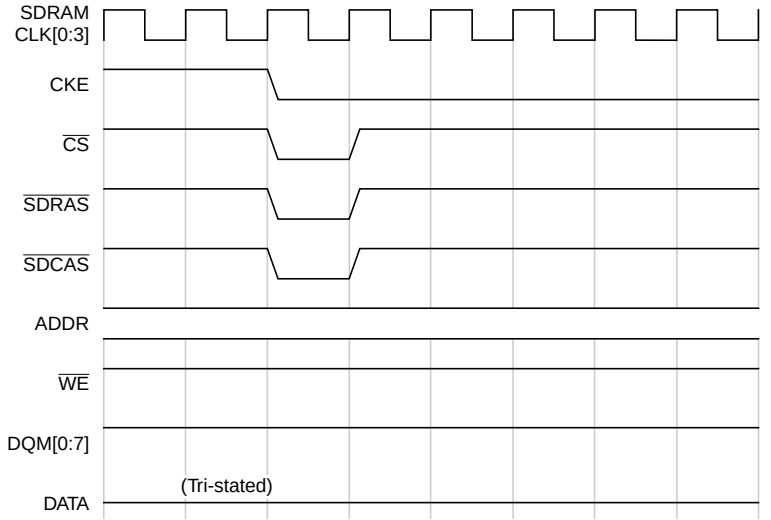

Figure 6-19. SDRAM Self Refresh Entry

The exit timing for self-refreshing SDRAMs is shown in Figure 6-20.

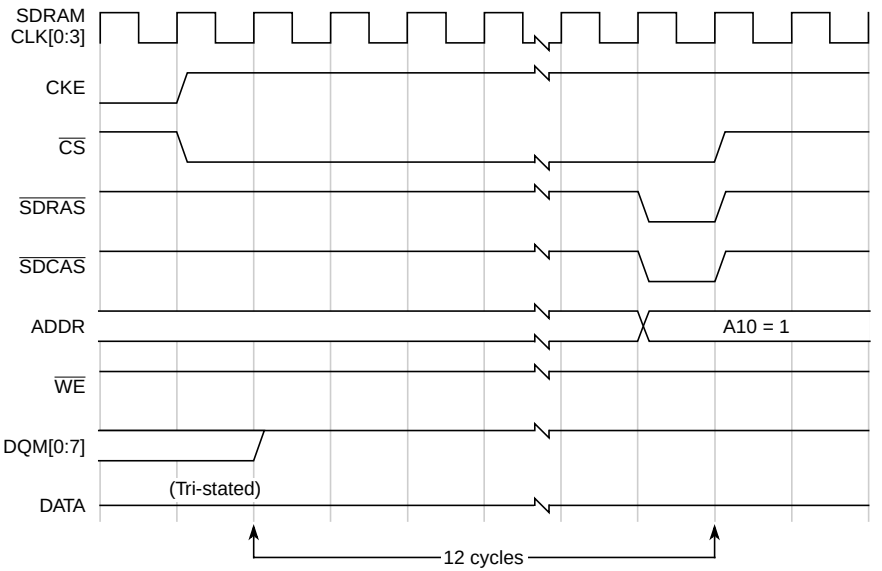

Figure 6-20. SDRAM Self Refresh Exit

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6.2.13 Processor-to-SDRAM Transaction Examples

The figures in this section provide examples of signal timing for 60x processor-to-SDRAM transactions. Figure 6-21 and Figure 6-22 show series of processor burst and single-beat reads to SDRAM. Figure 6-23 and Figure 6-24 show series of processor burst and single-beat writes to SDRAM. Figure 6-25 shows a series of processor single-beat reads followed by writes to SDRAM.

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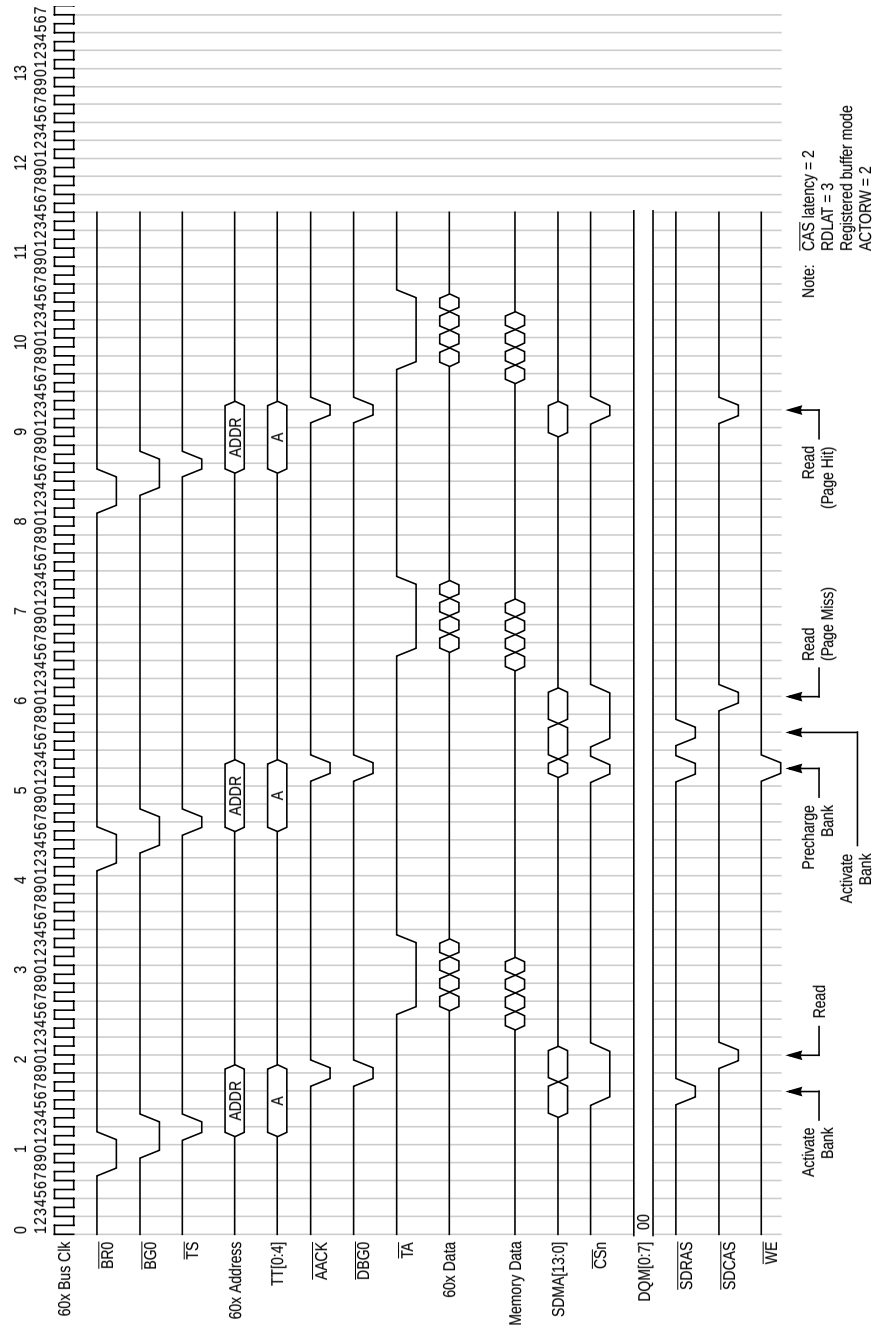

Figure 6-21. Processor Burst Reads from SDRAM

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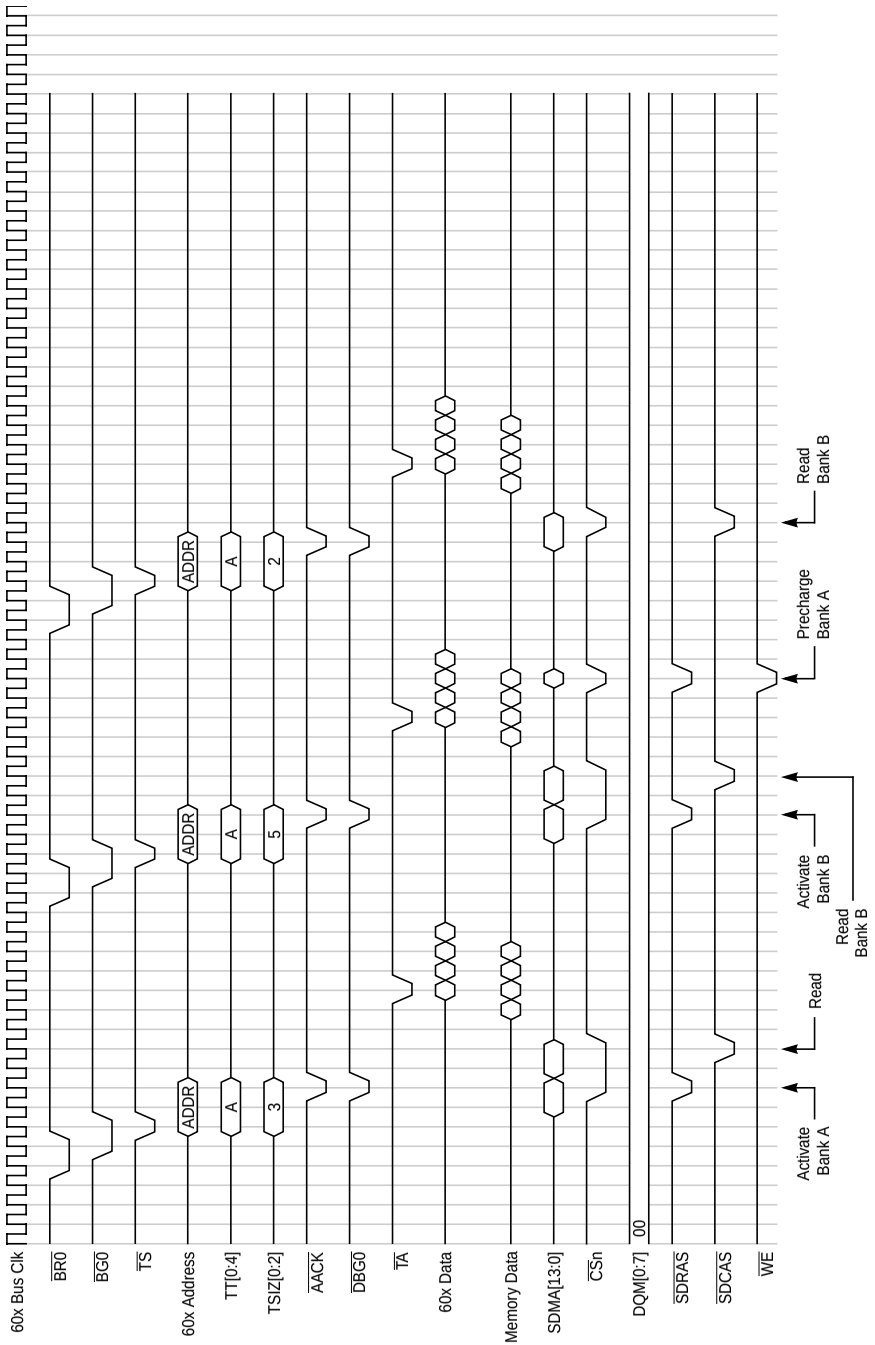

Figure 6-22. Processor Single-Beat Reads from SDRAM

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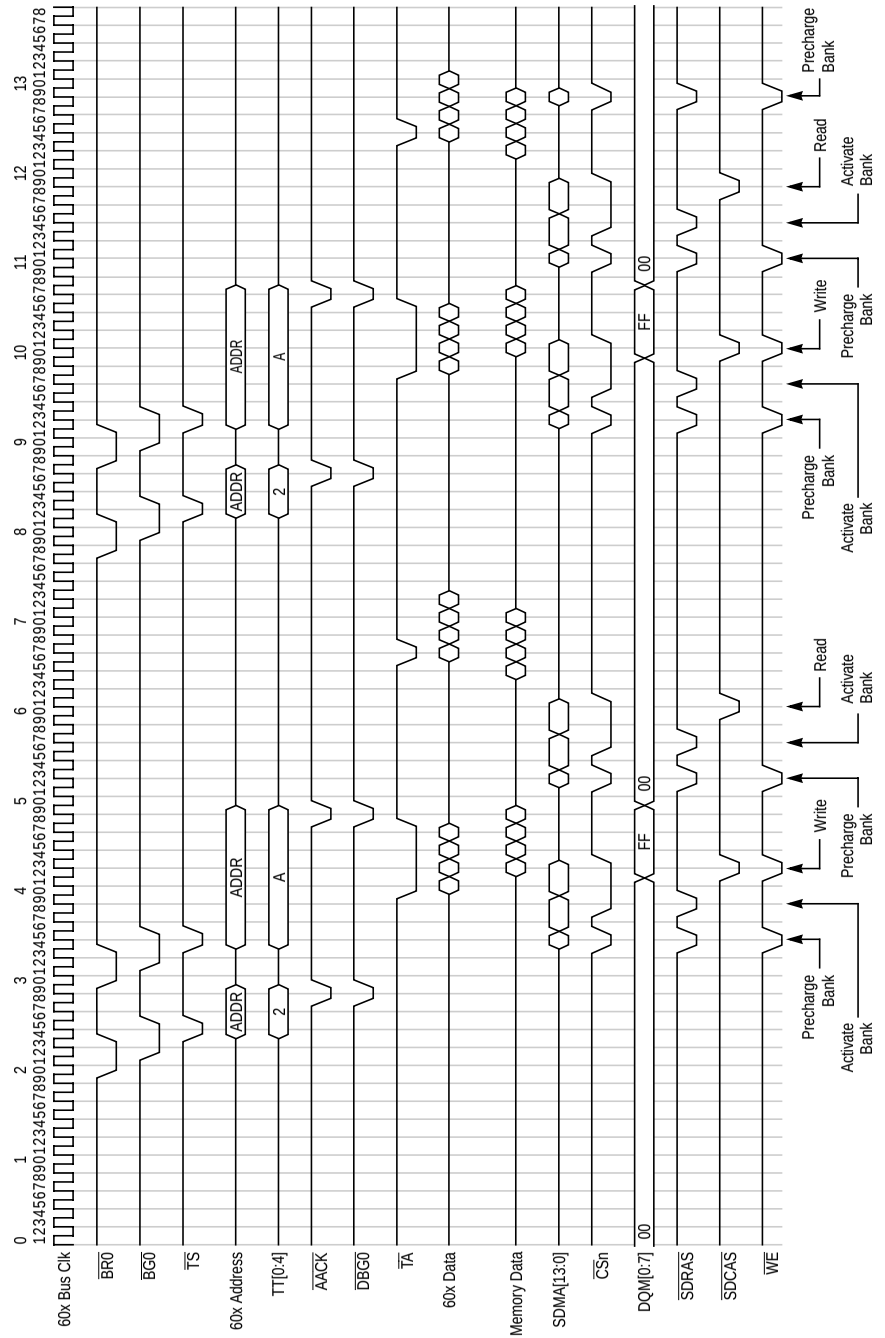

Figure 6-23. Processor Burst Writes to SDRAM

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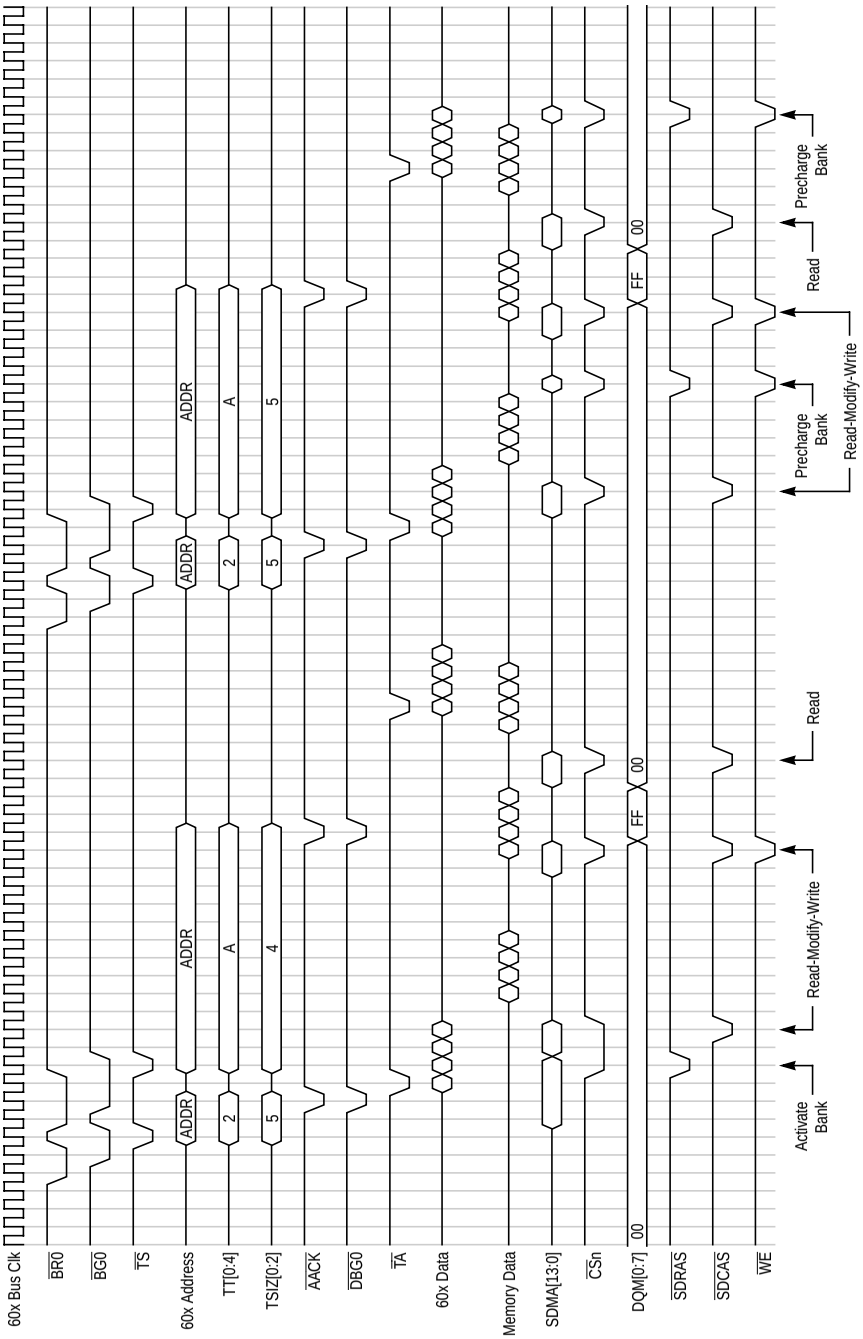

Figure 6-24. Processor Single-Beat Writes to SDRAM

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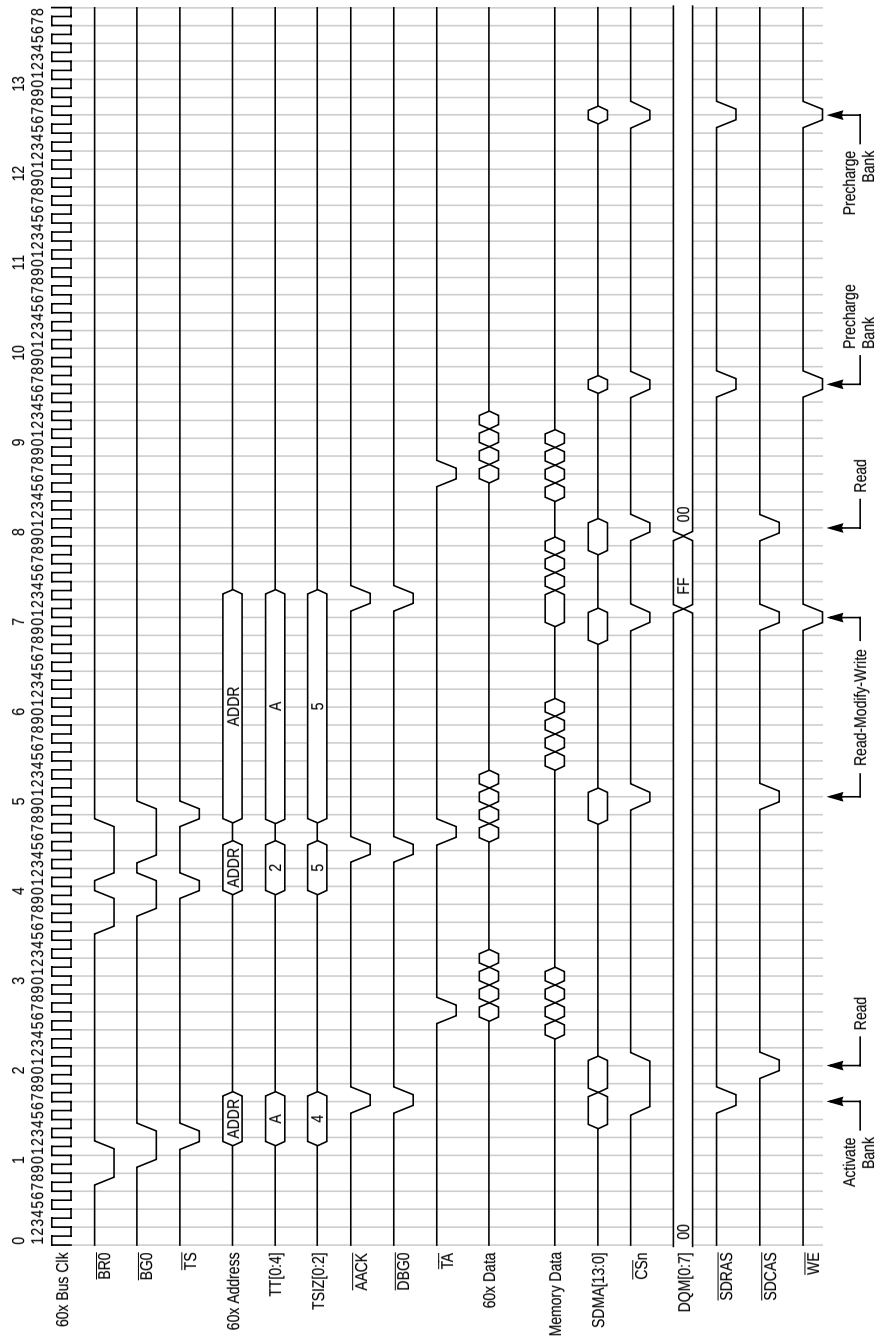

Figure 6-25. Processor Single-Beat Reads followed by Writes to SDRAM

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6.2.14 PCI-to-SDRAM Transaction Examples

The figures in this section provide examples of signal timing for PCI-to-SDRAM transactions. Figure 6-26 shows a series of PCI reads from SDRAM with Speculative Reads Enabled. Figure 6-27 shows a series of PCI reads from SDRAM with Speculative Reads Disabled. Figure 6-28 shows a series of PCI writes to SDRAM.

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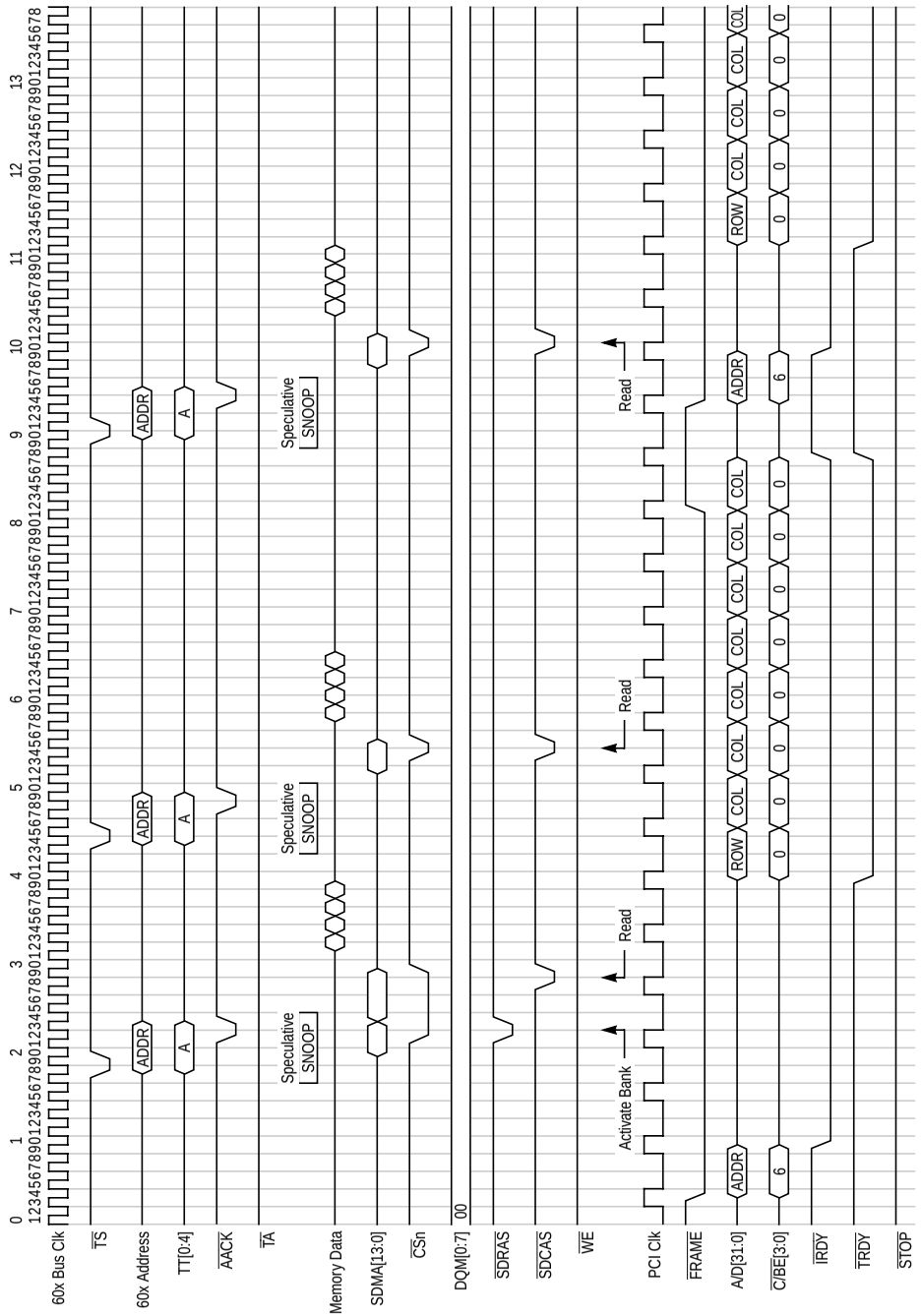

Figure 6-26. PCI Reads from SDRAM-Speculative Reads Enabled

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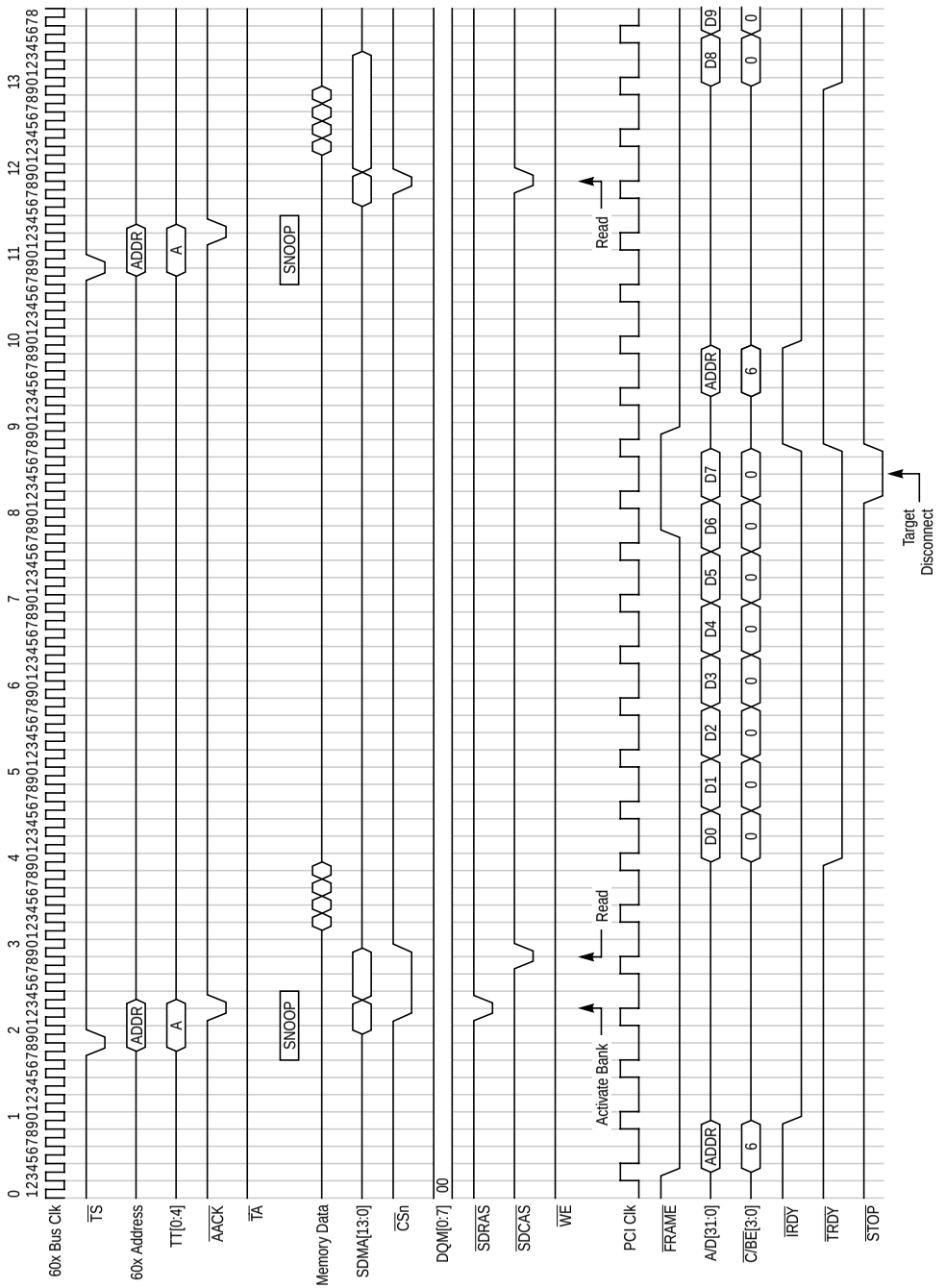

Figure 6-27. PCI Reads from SDRAM-Speculative Reads Disabled

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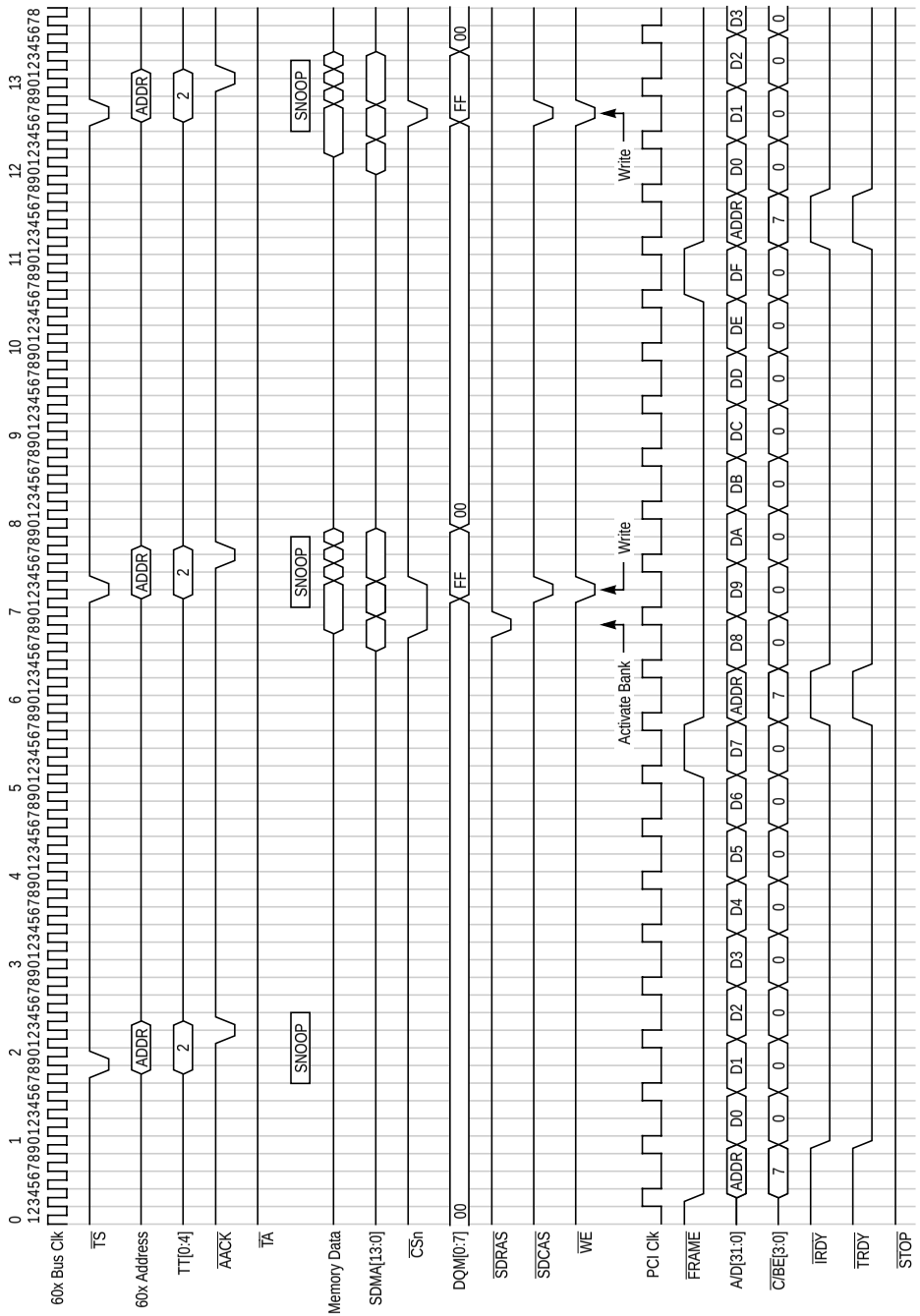

Figure 6-28. PCI Writes to SDRAM

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6.3 FPM or EDO DRAM Interface Operation

Figure 6-29 shows an internal block diagram of the FPM and EDO DRAM interface for the MPC8240.

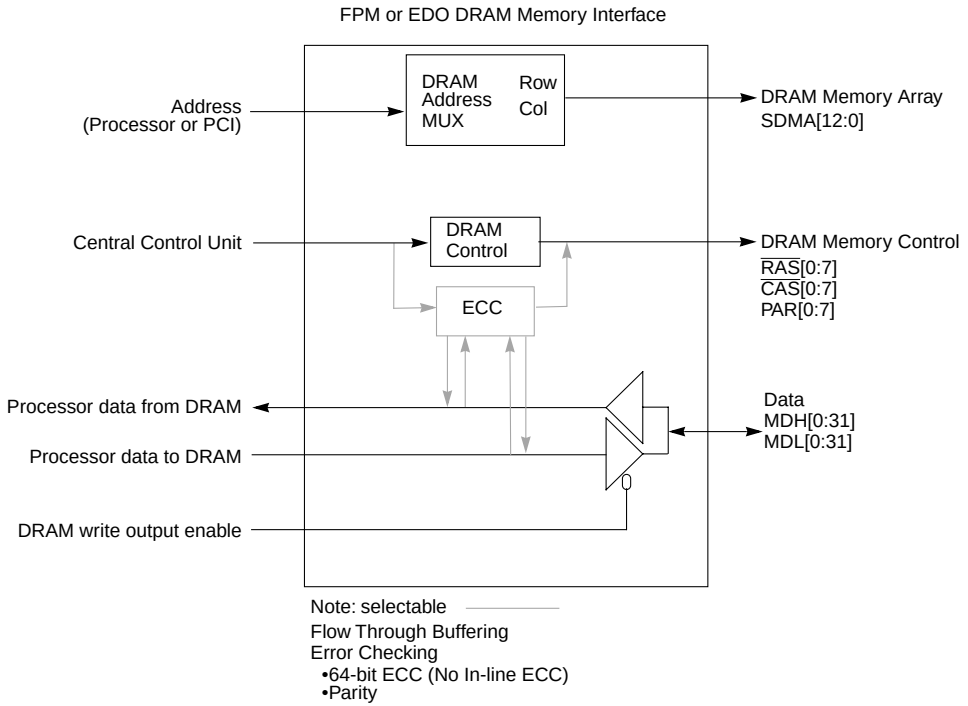

Figure 6-29. FPM or EDO DRAM Memory Interface Block Diagram

The MPC8240 supports a variety of DRAM configurations, through SIMM, DIMM, or direct board attachment. Thirteen address pins provide for DRAM device densities of up to 64 Mbits. Eight row address strobe ($\overline{RAS}$) signals support up to eight banks of memory. Each bank can be 8 bytes wide; eight column address strobe ($\overline{CAS}$) signals are used to provide byte selection for writes. The banks can be built of DRAMs, SIMMs or DIMMs that range from 4 to 128 Mbits as described in Table 6-17. The memory design must be byte-selectable for writes using $\overline{CAS}$. The MPC8240 allows up to 1 Gbyte of addressable memory.

In addition to the $\overline{CAS}$[0:7] signals, $\overline{RAS}$[0:7] signals, and address signals SDMA[12:0] and SDBA[1:0], there are 64 data signals MDH[0:31] and MDL[0:31], a write enable ($\overline{WE}$) signal, and one parity bit per byte-width of data PAR[0:7] for a total of 102 DRAM memory signals. Figure 6-30 is an example of a two-bank 16-Mbyte DRAM system. Figure 6-31 shows an example DRAM organization.

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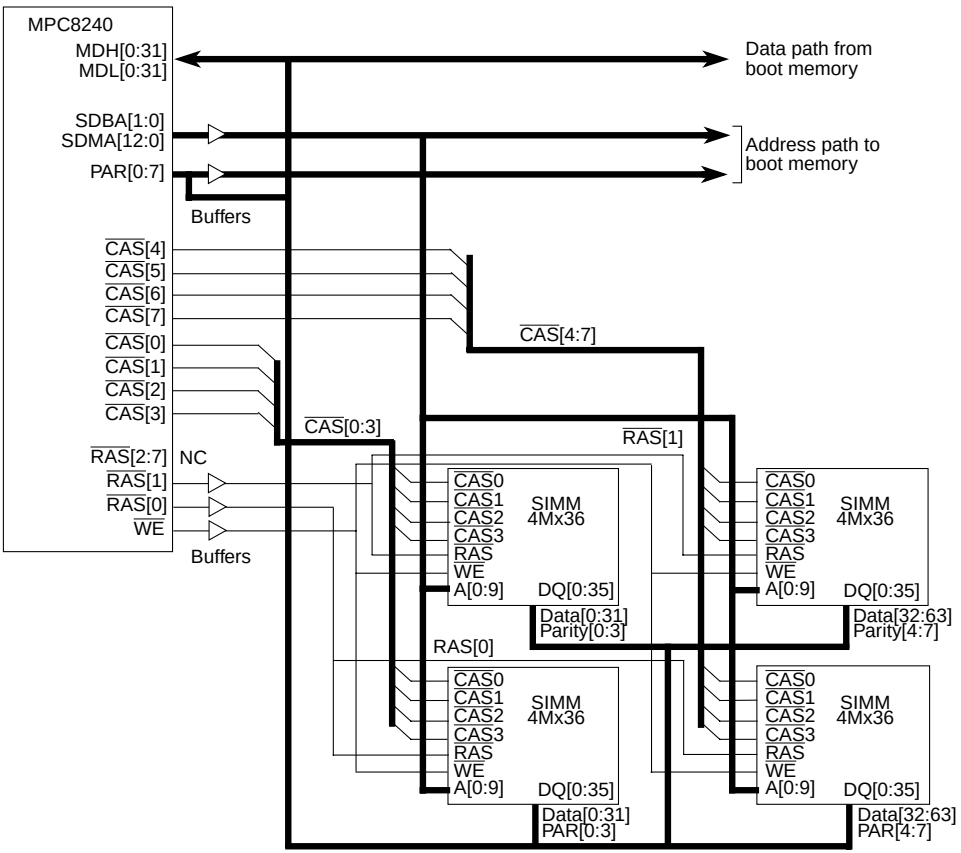
Some address and control signals may or may not require buffering, depending upon the system design. Analysis of the MPC8240 AC specifications, desired memory operating frequency, capacitive loads, and board routing loads assist the system designer in deciding whether any signals require buffering. See the *MPC8240 Hardware Specifications* for more information.



Address Signals (Outputs)	SDMA									
	9	8	7	6	5	4	3	2	1	0
Logical Names	msb				MA					lsb
	9	8	7	6	5	4	3	2	1	0

Figure 6-30. Example 16-Mbyte DRAM System with Parity—64-Bit Mode

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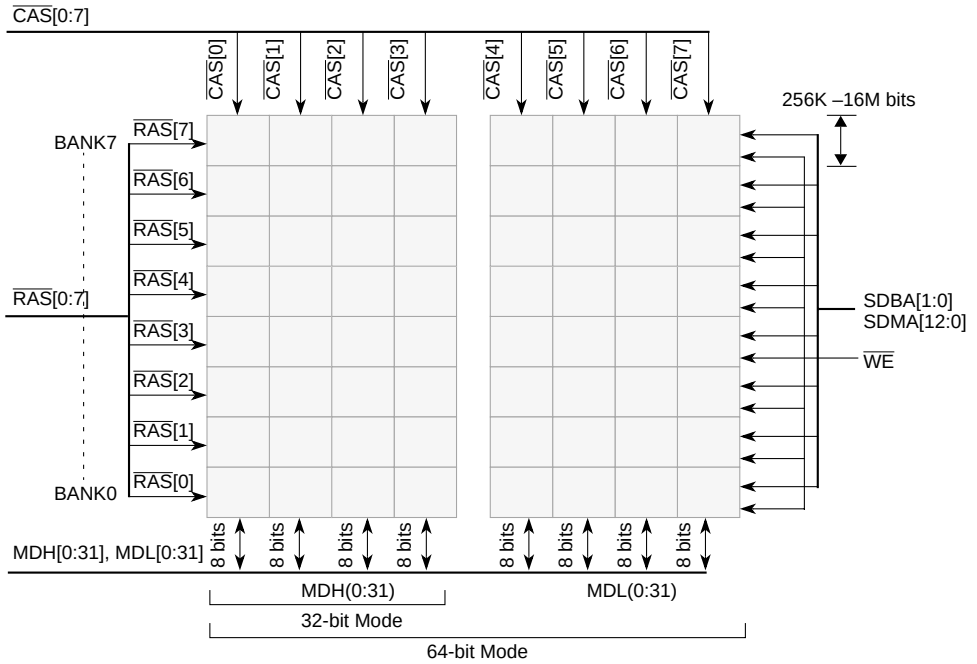

Figure 6-31. DRAM Memory Organization

6.3.1 Supported FPM or EDO DRAM Organizations

It is not necessary to use identical memory devices in each memory bank; individual memory banks may be of differing sizes but not of different type (SDRAM). The MPC8240 can be configured to provide 9–13 row bits to a particular bank, and 7–12 column bits. Table 6-17 summarizes the DRAM configurations supported by the MPC8240. This table is not exhaustive, although it covers most available DRAMs. The largest DRAM that can be supported is limited to 24 total address bits.

The MPC8240 can be configured at system start-up by using a memory-polling algorithm or hard code in a boot ROM, to map correctly the size of each bank in memory. The MPC8240 uses its bank map to assert the appropriate $\overline{\text{RAS}}$[0:7] signals for memory accesses according to the provided bank depths.

System software must also configure MCCR1 register in the MPC8240 at system start-up to appropriately multiplex the row and column address bits for each bank for the devices being used as shown in Table 6-17. Any unused banks should have their starting and ending addresses programmed out of the range of memory banks in use. Otherwise memory may become corrupted in the overlapping address range. Any unused banks should have their starting and ending addresses programmed out of the range of memory banks in use. Table 6-16 shows the unsupported multiplexed row and column address bit configurations in the 32- and 64-bit data bus mode. They result in non-contiguous address spaces.

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Table 6-16. Unsupported Multiplexed Row and Column Address Bits

32-bit Data Bus Mode	64-bit Data Bus Mode
13x10	13x10
13x9	13x9
13x8	13x8
12x8	—
12x7	12x7
11x8	–
11x7	11x7
10x8	—

Table 6-17. Supported FPM or EDO DRAM Device Configurations

DRAM Devices	Devices (64-bit Bank)	Device Configuration	Row x Column Bits	64-bit Bank Size (Mbytes)	8 Banks of Memory (Mbytes)
4 Mbits	4	256 Kbits x 16	9 x 9	2	16
	4	256 Kbits x 16	10 x 8 (64-bit only)	2	16
	8	512 Kbits x 8	10 x 9	4	32
	8	512 Kbits x 8	11 x 8 (64-bit only)	4	32
	16	1 Mbits x 4	10 x 10	8	64
	16	1 Mbits x 4	11 x 9	8	64
	64	4 Mbits x 1	12 x 10	32	256
	64	4 Mbits x 1	11 x 11	32	256
16 Mbits	2	512 Kbits x 32	11 x 8	4	32
	2	512 Kbits x 32	10 x 9	4	32
	4	1 Mbits x 16	12 x 8 (64-bit only)	8	64
	4	1 Mbits x 16	11 x 9	8	64
	4	1 Mbits x 16	10 x 10	8	64
	8	2 Mbits x 8	12 x 9	16	128
	8	2 Mbits x 8	11 x 10	16	128
	16	4 Mbits x 4	12 x 10	32	256
	16	4 Mbits x 4	11 x 11	32	256
	64	16 Mbits x 1	13 x 11	128	1024
	64	16 Mbits x 1	12 x 12	128	1024

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Table 6-17. Supported FPM or EDO DRAM Device Configurations (Continued)

DRAM Devices	Devices (64-bit Bank)	Device Configuration	Row x Column Bits	64-bit Bank Size (Mbytes)	8 Banks of Memory (Mbytes)
64 Mbits	2	2 Mbits x 32	12 x 9	16	128
	2	2 Mbits x 32	11 x 10	16	128
	4	4 Mbits x 16	12 x 10	32	256
	4	4 Mbits x 16	11 x 11	32	256
	8	8 Mbits x 8	12 x 11	64	512
	16	16 Mbits x 4	13 x 11	128	1024
	16	16 Mbits x 4	12 x 12	128	1024

6.3.2 FPM or EDO DRAM Address Multiplexing

System software must configure the MPC8240 at reset to appropriately multiplex the row and column address bits for each bank. This is done by writing the row address configuration into the memory control configuration register 1 (MCCR1); see Section 4.10, “Memory Control Configuration Registers.”

The internal physical addresses A[0_{msb}:31_{lsb}] is multiplexed through the output address pins SDMA[12:0]. The row and column bit configuration settings are shown in Figure 6-32 for 32-bit bus mode and Figure 6-33 for 64-bit bus mode. During the $\overline{RAS}$ and $\overline{CAS}$ phases, the unshaded row and column bits SDMA[12:0] multiplex the appropriate physical addresses.

6.3.2.1 Row Bit Multiplexing During The Row Phase ($\overline{RAS}$)

The following list shows the relationships between the internal physical addresses A[$5_{msb} – 20_{lsb}$] and the external address pins SDMA[12:0] during the assertion of $\overline{RAS}$:

- In the 32-bit data bus mode, SDMA12 contains A[6].
- In the 64-bit data bus mode SDMA12 contains A[5].
- If the FPM or EDO has 9 row bits, SDMA[8:0] contains A[12:20].
- If the FPM or EDO has 10 row bits, SDMA[9:0] contains A[11:20].
- If the FPM or EDO has 11 row bits, SDMA[10:0] contains A[10:20].
- If the FPM or EDO has 12 or 13 row bits, SDMA[11:0] contains A[9:20].

Note that SDMA12 is only used as the most-significant row address bit for 13 x 11 FPM or EDO arrays.

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6.3.2.2 Column Bit Multiplexing During the Column Phase ($\overline{CAS}$)

The following list shows the relationships between the internal physical addresses $A[21_{msb}–29_{lsb}]$ and the external address pins SDMA[7:0] during the assertion of $\overline{CAS}$:

- In the in 32-bit bus mode, SDMA[7:0] contains A[22:29].
- In the 64-bit bus mode, SDMA[7:0] contains A[21:28].

The encoding of SDMA[11:8] during $\overline{CAS}$ depends on the bus mode selected (32- or 64-bit) and on the number of row bits set in MCCR1 as shown in Table 6-18.

Table 6-18. SDMA[11:8] Encodings for 32- and 64-Bit Bus Modes

Row Bits	32-Bit Bus Mode	64-Bit Bus Mode
9	A[9:11, 21]	A[8:11]
10	A[8:10, 21]	A[7:10]
11	A[7:9, 21]	A[6:9]
12	A[6:8, 21]	A[5:8]
13	A[unused, 7:8, 21]	A[unused, 6:8]

6.3.2.3 Graphical View of the Row and Column Bit Multiplexing

Figure 6-32 and Figure 6-33 provide a graphical view of the row and column bit multiplexing.

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Row x Col		msb						Physical Address																												lsb
		0–5						6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
13x11	$\overline{RAS}$							12			11	10	9	8	7	6	5	4	3	2	1	0													
	$\overline{CAS}$								10	9													8	7	6	5	4	3	2	1	0		
12x12	$\overline{RAS}$										11	10	9	8	7	6	5	4	3	2	1	0													
	$\overline{CAS}$							11	10	9													8	7	6	5	4	3	2	1	0		
12x11	$\overline{RAS}$										11	10	9	8	7	6	5	4	3	2	1	0													
	$\overline{CAS}$								10	9													8	7	6	5	4	3	2	1	0		
12x10	$\overline{RAS}$										11	10	9	8	7	6	5	4	3	2	1	0													
	$\overline{CAS}$									9													8	7	6	5	4	3	2	1	0		
12x9	$\overline{RAS}$										11	10	9	8	7	6	5	4	3	2	1	0													
	$\overline{CAS}$																						8	7	6	5	4	3	2	1	0		
11x11	$\overline{RAS}$											10	9	8	7	6	5	4	3	2	1	0													
	$\overline{CAS}$									10	9												8	7	6	5	4	3	2	1	0		
11x10	$\overline{RAS}$											10	9	8	7	6	5	4	3	2	1	0													
	$\overline{CAS}$										9												8	7	6	5	4	3	2	1	0		
11x9	$\overline{RAS}$											10	9	8	7	6	5	4	3	2	1	0													
	$\overline{CAS}$																						8	7	6	5	4	3	2	1	0		
10x10	$\overline{RAS}$												9	8	7	6	5	4	3	2	1	0													
	$\overline{CAS}$											9											8	7	6	5	4	3	2	1	0		
10x9	$\overline{RAS}$												9	8	7	6	5	4	3	2	1	0													
	$\overline{CAS}$																						8	7	6	5	4	3	2	1	0		
9x9	$\overline{RAS}$													8	7	6	5	4	3	2	1	0													
	$\overline{CAS}$																						8	7	6	5	4	3	2	1	0		

Figure 6-32. DRAM Address Multiplexing SDMA[12:0]—32 Bit Mode

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Row x Col		msb Physical Address lsb																															
		0–4				5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
13x11	$\overline{RAS}$					12				11	10	9	8	7	6	5	4	3	2	1	0												
	$\overline{CAS}$						10	9	8													7	6	5	4	3	2	1	0			
12x12	$\overline{RAS}$									11	10	9	8	7	6	5	4	3	2	1	0												
	$\overline{CAS}$					11	10	9	8													7	6	5	4	3	2	1	0			
12x11	$\overline{RAS}$									11	10	9	8	7	6	5	4	3	2	1	0												
	$\overline{CAS}$						10	9	8													7	6	5	4	3	2	1	0			
12x10	$\overline{RAS}$									11	10	9	8	7	6	5	4	3	2	1	0												
	$\overline{CAS}$							9	8													7	6	5	4	3	2	1	0			
12x9	$\overline{RAS}$									11	10	9	8	7	6	5	4	3	2	1	0												
	$\overline{CAS}$								8													7	6	5	4	3	2	1	0			
12x8	$\overline{RAS}$									11	10	9	8	7	6	5	4	3	2	1	0												
	$\overline{CAS}$																					7	6	5	4	3	2	1	0			
11x11	$\overline{RAS}$										10	9	8	7	6	5	4	3	2	1	0												
	$\overline{CAS}$						10	9	8													7	6	5	4	3	2	1	0			
11x10	$\overline{RAS}$										10	9	8	7	6	5	4	3	2	1	0												
	$\overline{CAS}$								9	8												7	6	5	4	3	2	1	0			
11x9	$\overline{RAS}$										10	9	8	7	6	5	4	3	2	1	0												
	$\overline{CAS}$									8												7	6	5	4	3	2	1	0			
11x8	$\overline{RAS}$										10	9	8	7	6	5	4	3	2	1	0												
	$\overline{CAS}$																					7	6	5	4	3	2	1	0			
10x10	$\overline{RAS}$											9	8	7	6	5	4	3	2	1	0												
	$\overline{CAS}$									9	8											7	6	5	4	3	2	1	0			
10x9	$\overline{RAS}$											9	8	7	6	5	4	3	2	1	0												
	$\overline{CAS}$										8											7	6	5	4	3	2	1	0			
10x8	$\overline{RAS}$											9	8	7	6	5	4	3	2	1	0												
	$\overline{CAS}$																					7	6	5	4	3	2	1	0			
9x9	$\overline{RAS}$												8	7	6	5	4	3	2	1	0												
	$\overline{CAS}$										8											7	6	5	4	3	2	1	0			

Figure 6-33. DRAM Address Multiplexing SDMA[12:0]—64 Bit Mode

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6.3.3 FPM or EDO Memory Data Interface

The MPC8240 supports flow-through data path buffering for the DRAM data interface between the internal processor bus and external memory data bus, which must be configured as described in Table 6-19 and Table 6-20. Unspecified bit settings have undefined behavior.

Table 6-19. FPM or EDO Memory Parameters

Bit Name	Register and Offset	Bit Number in Register
RAM_TYPE	MCCR1 @ 0xF0	17
EDO	MCCR2 @ 0xF4	16
PCKEN	MCCR1 @ 0xF0	16
WRITE _PARITY_CHK	MCCR2 @ 0xF4	19
INLRD_PARECC_CHK_EN	MCCR2 @ 0xF4	18
INLINE_PAR_NOT_ECC	MCCR2 @ 0xF4	20
BUF_TYPE[0]	MCCR4 @ 0xFC	22
BUF_TYPE[1]	MCCR4 @ 0xFC	20
RMW_PAR	MCCR2 @ 0xF4	0
ECC_EN	MCCR2 @ 0xF4	17
MEM_PARITY_ECC_EN	ErrEnR1 @ 0xC0	2
MB_ECC_ERR_EN	ErrEnR2 @ 0xC4	3

Table 6-20. FPM or EDO System Configurations

RAM_TYPE	EDO	PCKEN	WRITE _PARITY_CHK	INLRD_PARECC _CHK_EN	INLINE_PAR_NOT_ECC	BUF_TYPE[0]	BUF_TYPE[1]	RMW_PAR	ECC_EN	MEM_PARITY_ECC_EN	MB_ECC_ERR_EN	Description
1	0	0	0	0	0	0	0	0	0	0	0	FPM, flow-through, no ECC or parity
1	1	0	0	0	0	0	0	0	0	0	0	EDO, flow-through, no ECC or parity
1	0	1	0	0	0	0	0	0	0	1	0	FPM, flow-through, parity enabled
1	1	1	0	0	0	0	0	0	0	1	0	EDO, flow-through, parity enabled
1	0	0	0	0	0	0	0	0	1	1	1	FPM, flow-through, ECC enabled
1	1	0	0	0	0	0	0	0	1	1	1	EDO, flow-through, ECC enabled
1	0	1	0	0	0	0	0	1	0	1	0	FPM, RMW_PAR
1	1	1	0	0	0	0	0	1	0	1	0	EDO, RWM_PAR

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The data path between the internal processor bus to the external memory bus in flow-through mode is shown in Figure 6-34. The flow-through mode is the default data bus buffering mode for the MPC8240.

Note that in-line ECC is not available with FPM or EDO DRAM.

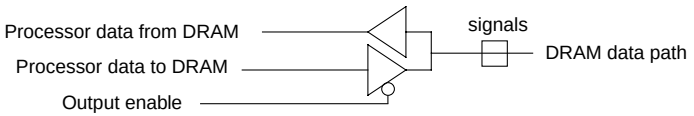

Figure 6-34. FPM-EDO Flow-through Memory Interface

6.3.4 FPM or EDO DRAM Initialization

At system reset, the main memory is inactive. When the reset signals ($\overline{\text{HRST\_CPU}}$ and $\overline{\text{HRST\_CTRL}}$) are negated, the MEMGO bit is cleared to zero (0) which turns off the memory controller. The processor 5core starts fetching boot code from ROM (local or PCI). For systems containing FPM or EDO DRAM, the boot code must set the MPC8240 configuration bit RAMTYP = 1.

Additionally, all other MPC8240 configuration registers relevant to DRAM must be initialized. Table 6-21 shows the register fields in the memory interface configuration registers (MICRs) and the memory control configuration registers (MCCRs).

Table 6-21. Memory Interface Configuration Register Fields

Register Field	Description	Configuration Register (and offset)
RAM_TYPE	SDRAM, FPM, or EDO DRAM	MCCR1 @ <F0>
Memory Bank Start and End Addresses		MICR @ <80>–<9C>
Memory Bank Enables		MICR @ <A0>
Row Address Bits For Each Bank		MCCR1 @ <F0>
PCKEN	Parity check enable	MCCR1 @ <F0>
SREN	Self refresh enable	MCCR1 @ <F0>
REFINT	Interval between refreshes	MCCR2 @ <F4>
RP1	$\overline{\text{RAS}}$ precharge interval	MCCR3 @ <F8>
RCD2	$\overline{\text{RAS}}$ to $\overline{\text{CAS}}$ delay	MCCR3 @ <F8>
CAS3	$\overline{\text{CAS}}$ assertion interval for first data beat	MCCR3 @ <F8>
CP4	$\overline{\text{CAS}}$ precharge interval	MCCR3 @ <F8>
CAS5	$\overline{\text{CAS}}$ assertion interval for page mode data beats	MCCR3 @ <F8>
RAS6P	$\overline{\text{RAS}}$ assertion interval for CBR refresh	MCCR3 @ <F8>
RMW_PAR	Read modify write parity	MCCR2 @ <F4>

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Table 6-21. Memory Interface Configuration Register Fields (Continued)

Register Field	Description	Configuration Register (and offset)
ECC_EN	ECC enable	MCCR2 @ <F4>
BUF_TYPE[1]	Registered data path = 0 (off)	MCCR4 @ <FC>
BUF_TYPE[0]	Cleared. In-line data path disabled.	MCCR4 @ <FC>
WRITE_PARITY_CHK	Enable write path parity error reporting	MCCR2 @ <F4>

After configuration of all these parameters is complete, the system software must set the configuration bit MEMGO which enables the memory controller. The MPC8240 performs one $\overline{CAS}$ before $\overline{RAS}$ (CBR) refresh cycle each time REFINT elapses. After eight refreshes, the main memory array is available for read and write accesses.

6.3.5 FPM or EDO DRAM Interface Timing

The read and write timing for DRAM is also controlled through programmable registers. These registers are programmed by system software at system start-up to control:

- $\overline{RAS}$ precharge time (RP_1)
- $\overline{RAS}$ to $\overline{CAS}$ delay time (RCD_2)
- $\overline{CAS}$ pulse width for the first access (CAS_3)
- $\overline{CAS}$ precharge time (CP_4)
- $\overline{CAS}$ pulse width in page mode (CAS_5)

All signal transitions occur on system clock rising edges. Figure 6-36 shows DRAM read timing with the programmable variables. Figure 6-38 shows DRAM write timing with the programmable variables. As shown, the provided timing variables are applicable to both read and write timing configuration. System software is responsible for optimal configuration of these parameters after reset. This configuration process must be completed at system start-up before any attempts to access DRAM. The actual values used by boot code depend on the memory technology used.

Note that no more than 8 PCI clock cycles should elapse between successive assertions of $\overline{CAS}$ within a burst.

Table 6-22 defines the timing parameters for FPM or EDO DRAM. Subscripts identify timing variables.

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Table 6-22. FPM or EDO Timing Parameters

Symbol	Timing Parameter
AA	Access time from column address
ASC	Column address setup time
ASR	Row address setup time
CAC	Access time from $\overline{CAS}$
CAH	Column address hold time
CAS_3	$\overline{CAS}$ assertion interval for a single beat, or for the first access in a burst
CAS_5	$\overline{CAS}$ assertion interval for page mode access
CHR	$\overline{CAS}$ hold time for CBR refresh
CP	$\overline{CAS}$ precharge time
CP_4	$\overline{CAS}$ precharge interval during page-mode access
CRP	$\overline{CAS}$ to $\overline{RAS}$ precharge time
CSH	$\overline{CAS}$ hold time
CSP	$\overline{CAS}$ setup time for CBR refresh
DH	Data in hold time
DS	Data in setup time
PC	Fast page mode cycle time
RAC	Access time from $\overline{RAS}$
RAD	$\overline{RAS}$ to column address delay time
RAH	Row address hold time
RAL	Column address to $\overline{RAS}$ lead time
RAS_{6P}	$\overline{RAS}$ assertion interval for CBR refresh
RASP	$\overline{RAS}$ pulse width (page mode)
RASS	Self-refresh interval (power saving modes only)
RC	Random access (read, write, or refresh) cycle time
RCD_2	$\overline{RAS}$ to $\overline{CAS}$ delay interval
RHCP	$\overline{RAS}$ hold time from $\overline{CAS}$ precharge (page mode only)
RP_1	$\overline{RAS}$ precharge interval
RPC	$\overline{RAS}$ precharge to $\overline{CAS}$ active time
RSH	$\overline{RAS}$ hold time
WCH	Write command hold time (referenced to $\overline{CAS}$)
WCS	Write command setup time
WP	Write command pulse width
WRH	Write to $\overline{RAS}$ hold time (CBR refresh)
WRP	Write to $\overline{RAS}$ precharge time (CBR refresh)

Note that all signal transitions occur on the rising edge of the memory bus clock.

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Figure 6-35 through Figure 6-40 shows FPM or EDO timing for various types of accesses with ECC disabled.

Figure 6-35 shows a single-beat read operation

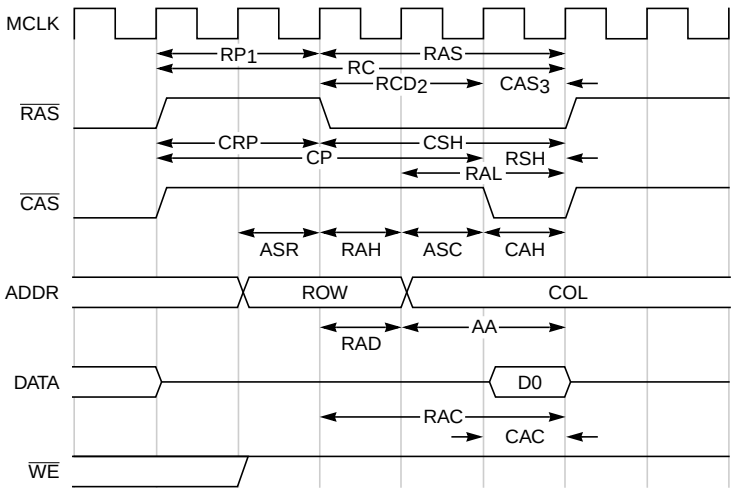

Figure 6-35. DRAM Single-Beat Read Timing (No ECC)

Figure 6-36 shows a 64-bit bus mode burst read operation.

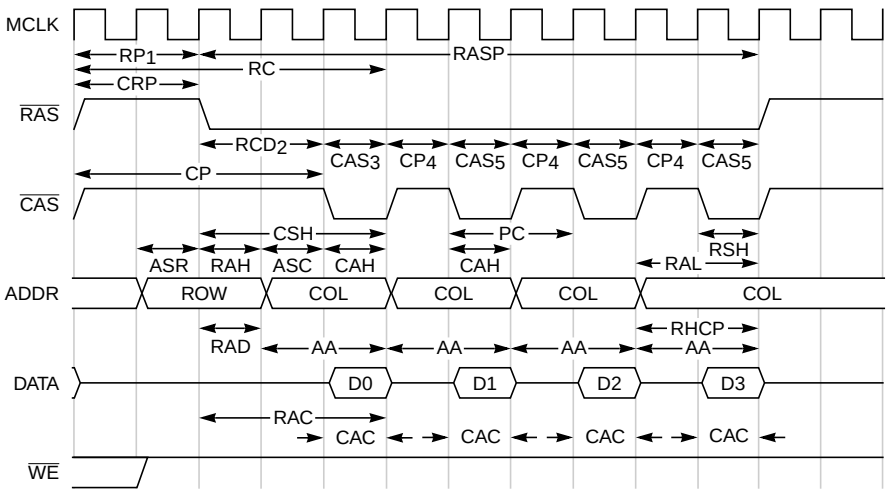

Figure 6-36. DRAM Four-Beat Burst Read Timing (No ECC)—64-Bit Mode

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Figure 6-37 shows a 32-bit bus mode burst read operation.

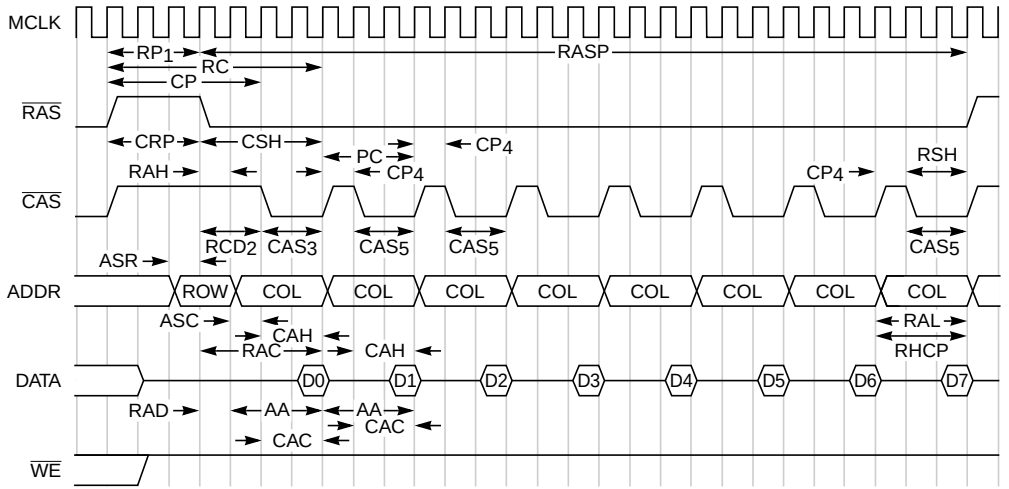

Figure 6-37. DRAM Eight-Beat Burst Read Timing Configuration—32-Bit Mode

Figure 6-38 shows a single-beat write operation.

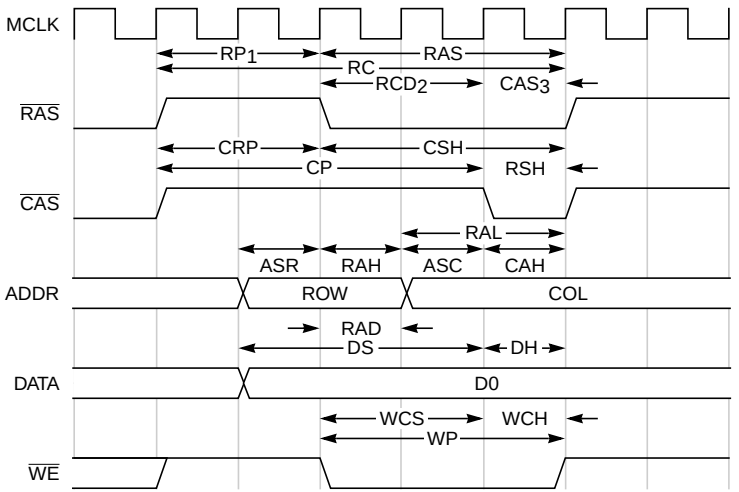

Figure 6-38. DRAM Single-Beat Write Timing (No ECC)

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Figure 6-39 shows a 64-bit bus mode burst write operation.

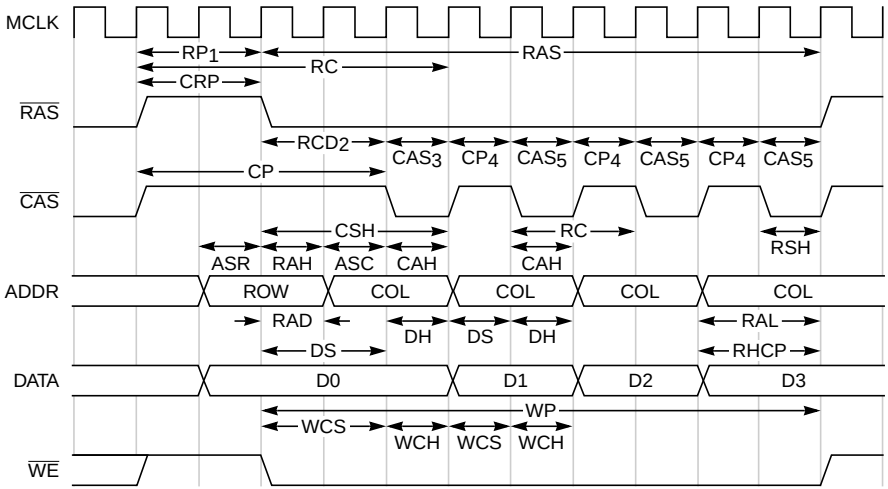

Figure 6-39. DRAM Four-Beat Burst Write Timing (No ECC)—64-Bit Mode

Figure 6-40 shows a 32-bit bus mode burst write operation.

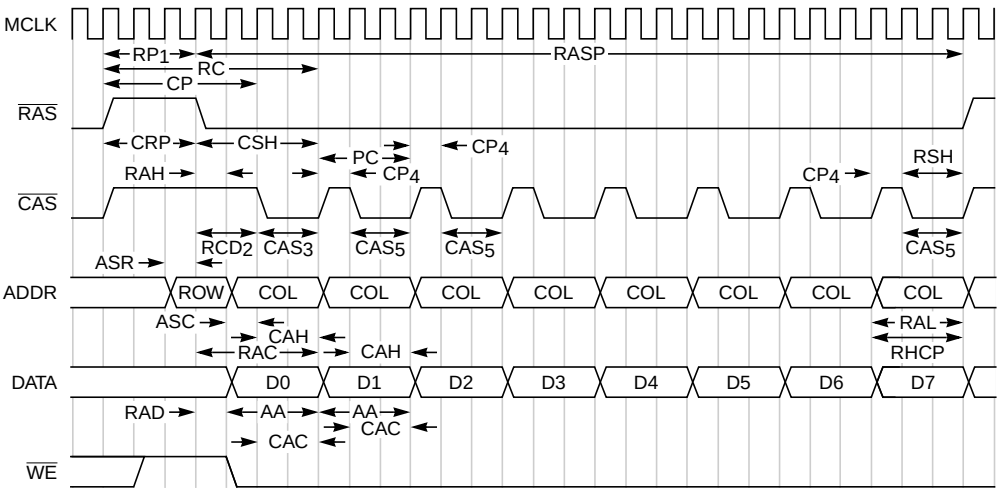

Figure 6-40. DRAM Eight-beat Burst Write Timing (No ECC)—32 Bit Mode

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6.3.6 DMA Burst Wrap

The MPC8240 supports burst-of-four data beats for accesses with a 64-bit data path and burst-of-eight data beats for accesses with a 32-bit data path. The burst is always sequential, and the critical double word is always supplied first as detailed in the following two examples:

- Using a 64-bit data path, if the processor core requests the third double word (DW2) of a cache line, the MPC8240 reads double words from memory in the order DW2-DW3-DW0-DW1.
- Using a 32-bit data path, if the processor core requests the third double word (W4 and W5) of a cache line, the MPC8240 reads words from memory in the order W4-W5-W6-W7-W0-W1-W2-W3.

6.3.7 FPM or EDO DRAM Page Mode Retention

Under certain conditions, the MPC8240 retains the currently active FPM or EDO page by holding $\overline{\text{RAS}}$ asserted for pipelined burst accesses. These conditions are as follows:

- A pending transaction (read or write) hits the currently active FPM or EDO page.
- There are no pending refreshes.
- The maximum $\overline{\text{RAS}}$ assertion interval (controlled by PGMAX) has not been exceeded.

Page mode can dramatically reduce access latencies for page hits. Depending on the memory system design and timing parameters, page mode can save three to four clock cycles from subsequent burst accesses that hit in an active page. Page mode is disabled by clearing the PGMAX parameter (PGMAX = 0x00) located in the memory page mode register (MPM). See Section 4.6.3, “Memory Page Mode Register—0xA3,” for more information.

6.3.8 FPM or EDO DRAM Parity and RMW Parity

When configured for FPM or EDO, the MPC8240 supports two forms of parity checking and generation—normal parity and read-modify-write (RMW) parity. Normal parity assumes that each of the eight parity bits is controlled by a separate $\overline{\text{CAS}}$ signal. Thus, for a single-beat write from PCI to system memory, the MPC8240 generates a parity bit for each byte written to memory.

RMW parity assumes that all eight parity bits are controlled by a single $\overline{\text{CAS}}$ signal; therefore it must be written as a single 8-bit quantity (byte). Thus, for any write operation to system memory that is less than a double word, the MPC8240 must latch the write data, read an entire 64-bit double word from memory, check the parity of that double word, merge the write data with that double word, regenerate parity for the new double word, and finally write the new double word back to memory.

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The MPC8240 checks parity on all memory reads, provided parity checking is enabled (PCKEN = 1). The MPC8240 generates parity for the following operations:

- PCI-to-memory write operations
- Processor single-beat write operations with RMW parity enabled (RMW_PAR = 1)

The processor core is expected to generate parity for all other memory write operations as the data goes directly to memory.

Note that the MPC8240 does not support RMW parity mode when in 32-bit data path mode (RMW_PAR = 0).

6.3.8.1 RMW Parity Latency Considerations

When RMW parity is enabled, the time required to read, modify, and write increases latency for some transactions.

For processor core single-beat writes to system memory, the MPC8240 latches the data, performs a double-word read from system memory (checking parity), and then merges the write data from the processor with the data read from memory. The MPC8240 then generates new parity bits for the merged double word and writes the data and parity to memory. The read-modify-write process adds six clock cycles to a single-beat write operation. If page-mode retention is enabled (PGMAX > 0), then the MPC8240 keeps the memory in page mode for the read-modify-write sequence. Figure 6-41 shows FPM or EDO timing for a local processor single-beat write operation with RMW parity enabled.

For PCI writes to system memory with RMW parity enabled, the MPC8240 latches the data in the internal PCI-to-system-memory-write buffer (PCMWB). If the PCI master writes complete double words to system memory, the MPC8240 generates the parity bits when the PCMWB is flushed to memory. However, if the PCI master writes 32-, 16-, or 8-bit data that cannot be gathered into a complete double word in the PCMWB, a read-modify-write operation is required. The MPC8240 performs a double-word read from system memory (checking parity), and then merges the write data from the PCI master with the data read from memory. The MPC8240 then generates new parity for the merged double word and writes the data and parity to memory. If page mode retention is enabled (PGMAX > 0), the MPC8240 keeps the memory in page mode for the read-modify-write sequence.

Because the local processor drives all eight parity bits during burst writes to system memory, these transactions go directly to the DRAMs with no performance penalty. All other transactions are unaffected and operate as in normal parity mode.

6.3.9 FPM or EDO ECC

As an alternative to simple parity, the MPC8240 supports ECC for the data path between the MPC8240 and system memory. ECC not only allows the MPC8240 to detect errors in

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the memory data path but also to correct single-bit errors in the 64-bit data path. The ECC logic in the MPC8240 detects and corrects all single-bit errors and detects all double-bit errors and all errors within a nibble. Other errors may be detected but are not guaranteed to be either detected or corrected. Multiple-bit errors are always reported when detected. However, when a single-bit error occurs, the single-bit error counter register is incremented, and its value is compared to the single-bit error trigger register. If the values are not equal, no error is reported; if the values are equal, then an error is reported. Thus, the single-bit error registers may be programmed so that minor faults with memory are corrected and ignored, but a catastrophic memory failure generates an interrupt. The syndrome equations for the ECC code are shown in Table 6-23 and Table 6-24. For supported configurations, see Table 6-17.

Table 6-23. The MPC8240 FPM or EDO ECC Syndrome Encoding (Data bits 0:31)

Syndrome Bit	Data Bit																															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				x				x				x				x
1	x				x				x				x				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2		x				x				x				x			x				x				x				x			
3			x				x				x				x			x				x				x				x		
4				x				x				x				x			x	x			x	x			x	x			x	x
5					x	x	x	x					x	x	x	x					x	x	x	x					x	x	x	x
6									x	x	x	x	x	x	x	x									x	x	x	x	x	x	x	x
7	x	x	x	x									x	x	x	x	x	x	x					x				x	x	x	x	

Table 6-24. The MPC8240 FPM or EDO ECC Syndrome Encoding (Data bits 32:63)

Syndrome Bit	Data Bit																															
	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
0			x				x				x				x					x				x				x		x		
1				x				x				x				x	x				x				x				x			x	
2	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x				x				x						x
3	x				x				x				x						x				x				x		x	x	x	x
4		x	x	x		x	x	x		x	x	x		x	x	x													x	x	x	x
5					x	x	x	x					x	x	x	x	x	x	x	x	x	x	x	x								
6									x	x	x	x	x	x	x	x	x	x	x	x					x	x	x	x	x	x	x	x
7	x	x					x	x			x	x	x	x							x	x	x	x	x	x	x	x		x	x	x

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The MPC8240 supports concurrent ECC for the FPM or EDO data path and parity for the processor core data path. ECC and parity may be independently enabled or disabled. The eight signals used for ECC (PAR[0:7]) are also used for processor core parity. The MPC8240 checks ECC on all memory reads (provided ECC_EN = 1). The MPC8240 supports a read-modify-write mode similar to the RMW parity mode described above for writes smaller than double word writes. The MPC8240 does not support ECC when in 32-bit data path mode (ECC_EN = 0).

6.3.9.1 FPM or EDO DRAM Interface Timing with ECC

When ECC is enabled, the time required to check and generate the ECC codes increases access latency. Figure 6-39 through Figure 6-40 shows FPM or EDO timings for various types of accesses with ECC enabled.

For processor burst reads from system memory, checking the ECC codes for errors requires two additional clock cycles for the first data returned and at least four clock cycles for subsequent beats. These requirements do not depend on the buffer type or whether FPM or EDO is used for system memory.

For processor core single-beat writes to system memory, the MPC8240 latches the data, performs a double-word read from system memory (checking and correcting any ECC errors), and merges the write data from the processor with the data read from memory. The MPC8240 then generates a new ECC code for the merged double word and writes the data and ECC code to memory. This read-modify-write process adds six clock cycles to a single-beat write operation. If page mode retention is enabled (PGMAX > 0), the MPC8240 keeps the memory in page mode for the read-modify-write sequence.

For processor core burst writes to system memory, the MPC8240 latches the data in the internal copyback buffer and flushes the buffer to memory at the earliest opportunity. The MPC8240 generates the ECC codes when the flush occurs. Note that the MPC8240 does not check the data being overwritten in memory.

For PCI writes to system memory with ECC enabled, the MPC8240 latches the data in the internal PCI to memory write buffer (PCMWB). If the PCI master writes complete double words to system memory, the MPC8240 generates the ECC codes when the PCMWB is flushed to memory.

If the PCI master writes 32-, 16-, or 8-bit data that cannot be gathered into a complete double word in the PCMWB, a read-modify-write operation is required.

The MPC8240 performs a double-word read from system memory (checking and correcting any ECC errors), then merges the write data from the PCI master with the data read from memory, generates a new ECC code for the merged double word, and writes the data and ECC code to memory.

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Figure 6-41 shows a FPM burst read operation.

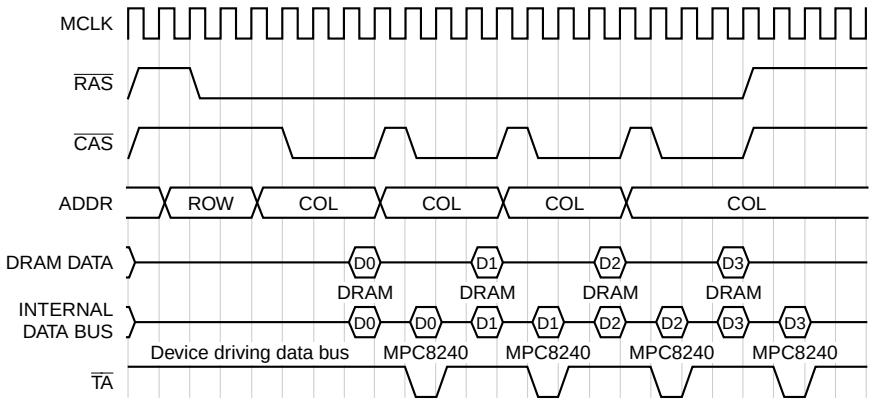

Figure 6-41. FPM DRAM Burst Read with ECC

Figure 6-42 shows an EDO burst read operation.

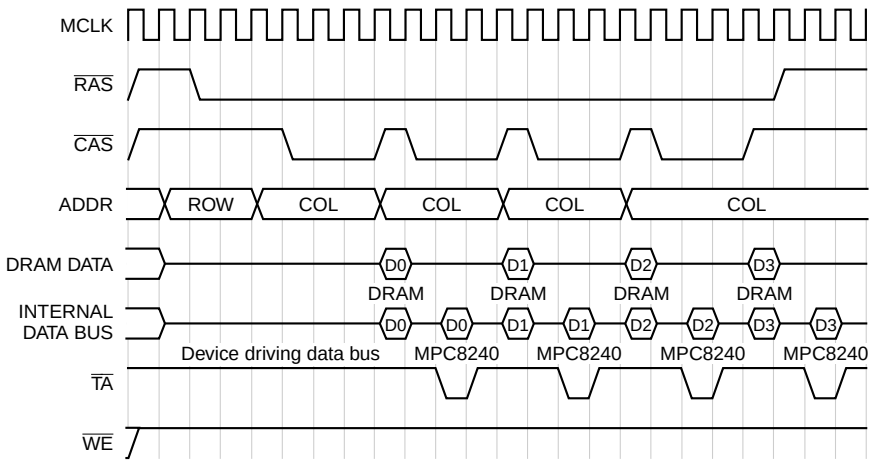

Figure 6-42. EDO DRAM Burst Read Timing with ECC

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Figure 6-43 shows a single-beat write operation.

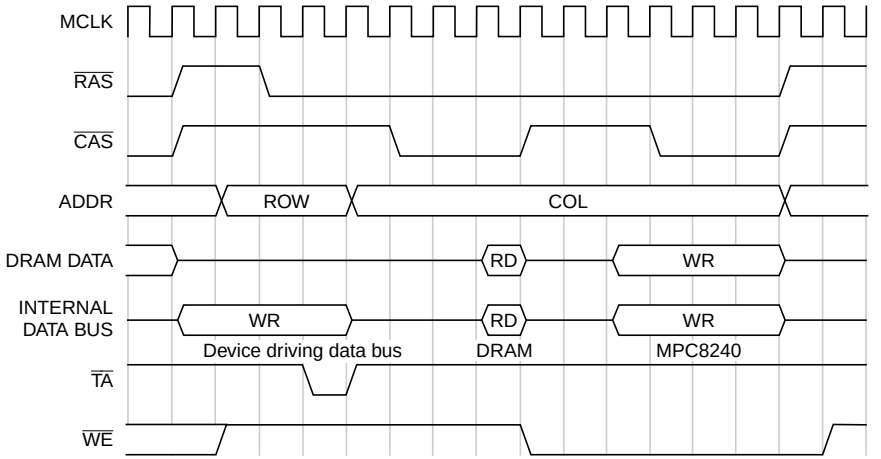

Figure 6-43. DRAM Single-Beat Write Timing with RMW or ECC Enabled

6.3.10 FPM or EDO DRAM Refresh

The MPC8240's memory interface distributes $\overline{\text{CAS}}$-before-$\overline{\text{RAS}}$ (CBR) refreshes to DRAM according to the interval specified in the MCCR2[REFINT] parameter. MCCR2 must be programmed by boot code at system start-up. The value to be stored in REFINT represents the number of memory clock cycles required between CBR refreshes.

This value should allow for a potential collision between memory access and refresh. (The per row refresh interval should be reduced by the longest memory access time.) For example, for a DRAM with a cell refresh time of 64 mS and 4096 rows, the per row refresh interval would be 64 mS/4,096 rows = 15.6 µS. If the memory interface runs at 66 MHz, 15.6 µS represents 1,030 memory clock cycles. If a burst read is in progress when a refresh is to be performed, the refresh waits for the read to complete. Thus, the per-row refresh interval (1,030 clocks) should be reduced by the longest access time (based on configuration parameters) and then stored to REFINT (as a binary representation of the difference).

6.3.10.1 FPM or EDO Refresh Timing

The refresh timing for DRAM is controlled through MCCR3[RAS_{6P}]. This register is initialized during reset and controls the $\overline{\text{RAS}}$ active time during a CBR refresh. (Refer to interval RAS_{6P} in Figure 6-44.) As shown in the figure, the MPC8240 implements bank staggering for CBR refreshes. System software is responsible for optimal configuration of interval RAS_{6P} after system start-up. Such configuration must be completed before attempting access to DRAM.

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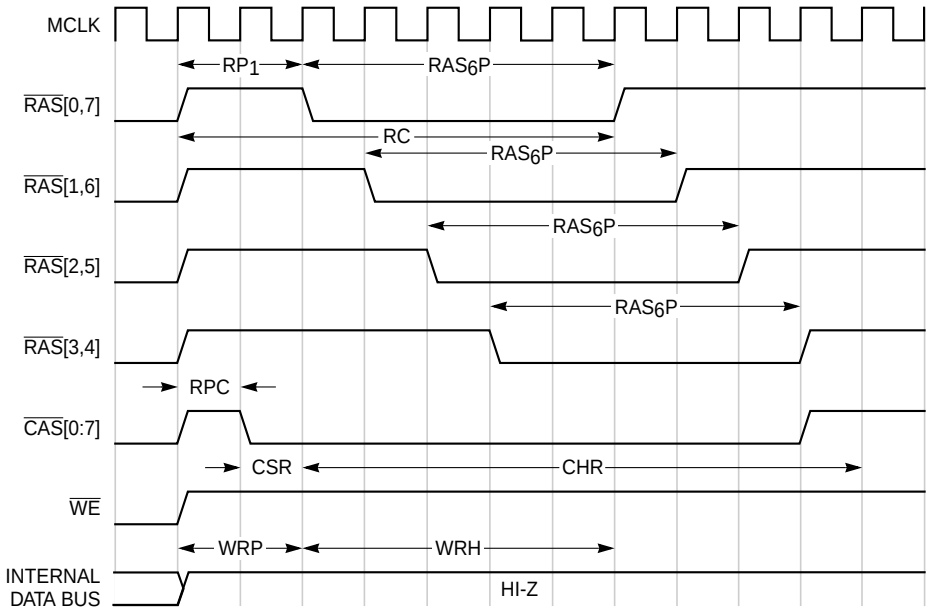

NOTES:
1. Subscripts identify programmable timing variable (RP1, RAS_6P).
2. RAS_6P = 1–8 cycles.
3. RPs = As configured for read or write timing.

Figure 6-44. DRAM Bank Staggered CBR Refresh Timing Configuration

6.3.11 FPM or EDO DRAM Power Saving Modes

The MPC8240's memory interface provides for sleep, doze, and nap power saving modes defined for the processor core. In doze and nap modes, the MPC8240 supplies normal CBR refresh to DRAM. In sleep mode, the MPC8240 can be configured to take advantage of DRAM self-refresh mode, to provide normal refresh to DRAM, or to provide no refresh support. If the MPC8240 is configured to provide no refresh support in sleep mode, system software must appropriately preserve DRAM data, that is by copying to disk.

See Chapter 14, "Power Management," for more information on the power saving modes of the MPC8240.

6.3.11.1 Configuration Parameters for DRAM Power Saving Modes

Table 6-25 provides a summary of the MPC8240 configuration bits relevant to power saving modes. In Table 6-25, PMCR1 refers to the MPC8240's power management configuration register 1, and MCCR1 refers to memory control configuration register 1.

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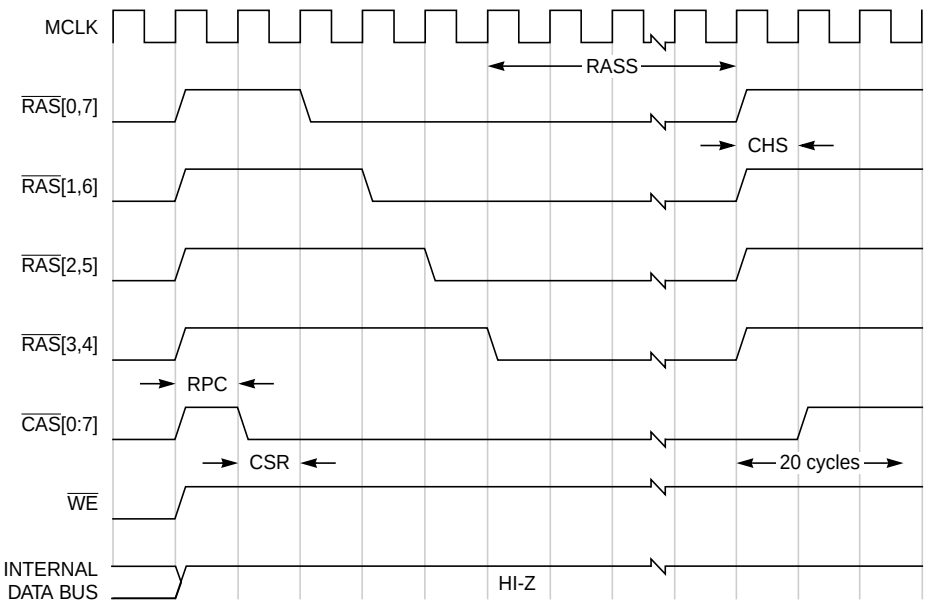
Table 6-25. FPM or EDO DRAM Power Saving Modes Refresh Configuration

Power Saving Mode	Refresh Type	Power Management Control Register (PMCR1)					MCCR1 [SREN]
		PM	DOZE	NAP	SLEEP	LP_REF_EN	
Doze	Normal	1	1	0	0	—	—
Nap	Normal	1	—	1	0	—	—
Sleep	Self	1	—	—	1	1	1
	Normal	1	—	—	1	1	0
	None	1	—	—	1	0	—

6.3.11.2 DRAM Self-Refresh in Sleep Mode

The MPC8240 allows the system designer to use DRAMs that provide self refresh for power-down situations. These DRAMs should be used if data retention is imperative during sleep mode. The MPC8240 properly configures these DRAMs during sleep mode if the appropriate configuration register bit is set. The timing for such a self refresh initiation is shown in Figure 6-45.



NOTE: RASS = Self-refresh interval (must be greater than 100 µs).

Figure 6-45. DRAM Self-Refresh Timing Configuration

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6.3.12 PCI-to-DRAM Transaction Examples

The figures in this section provide examples of signal timing for PCI-to-DRAM transactions. Figure 6-46 shows a series of PCI reads from DRAM with Speculative Reads Enabled. Figure 6-47 shows a series of PCI reads from DRAM with Speculative Reads Disabled. Figure 6-48 shows a series of PCI writes to DRAM.

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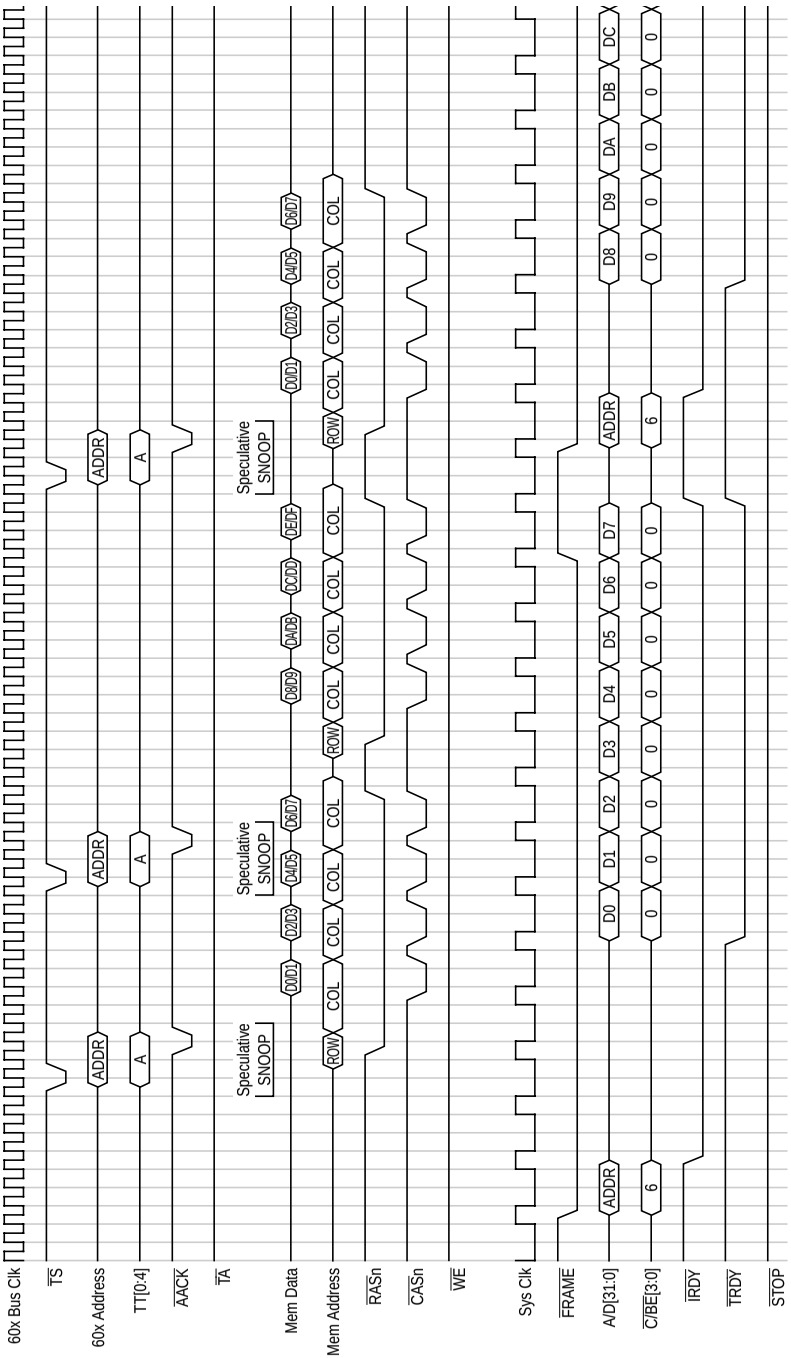

Figure 6-46. PCI Reads from DRAM-Speculative Reads Enabled

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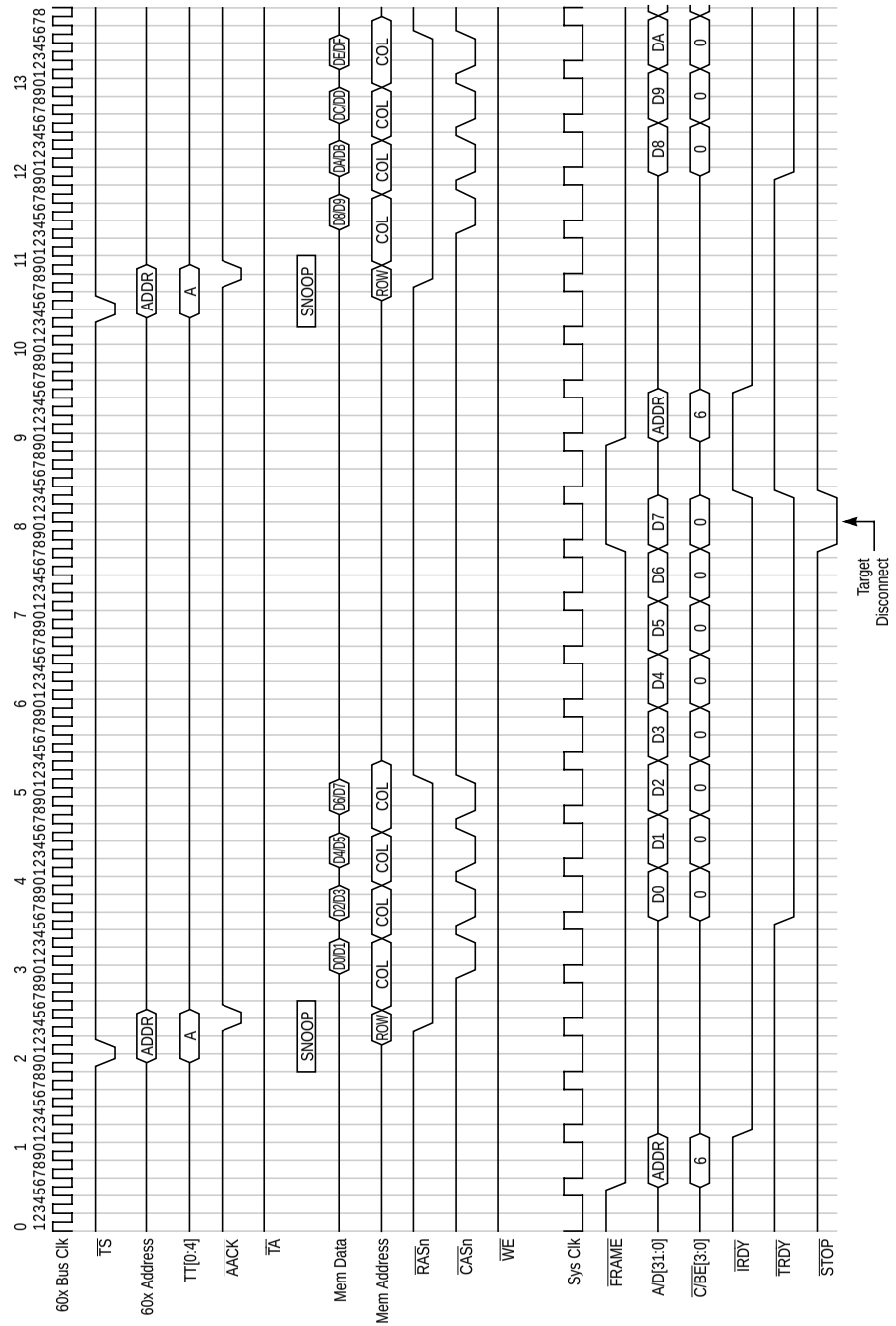

Figure 6-47. PCI Reads from DRAM-Speculative Reads Disabled

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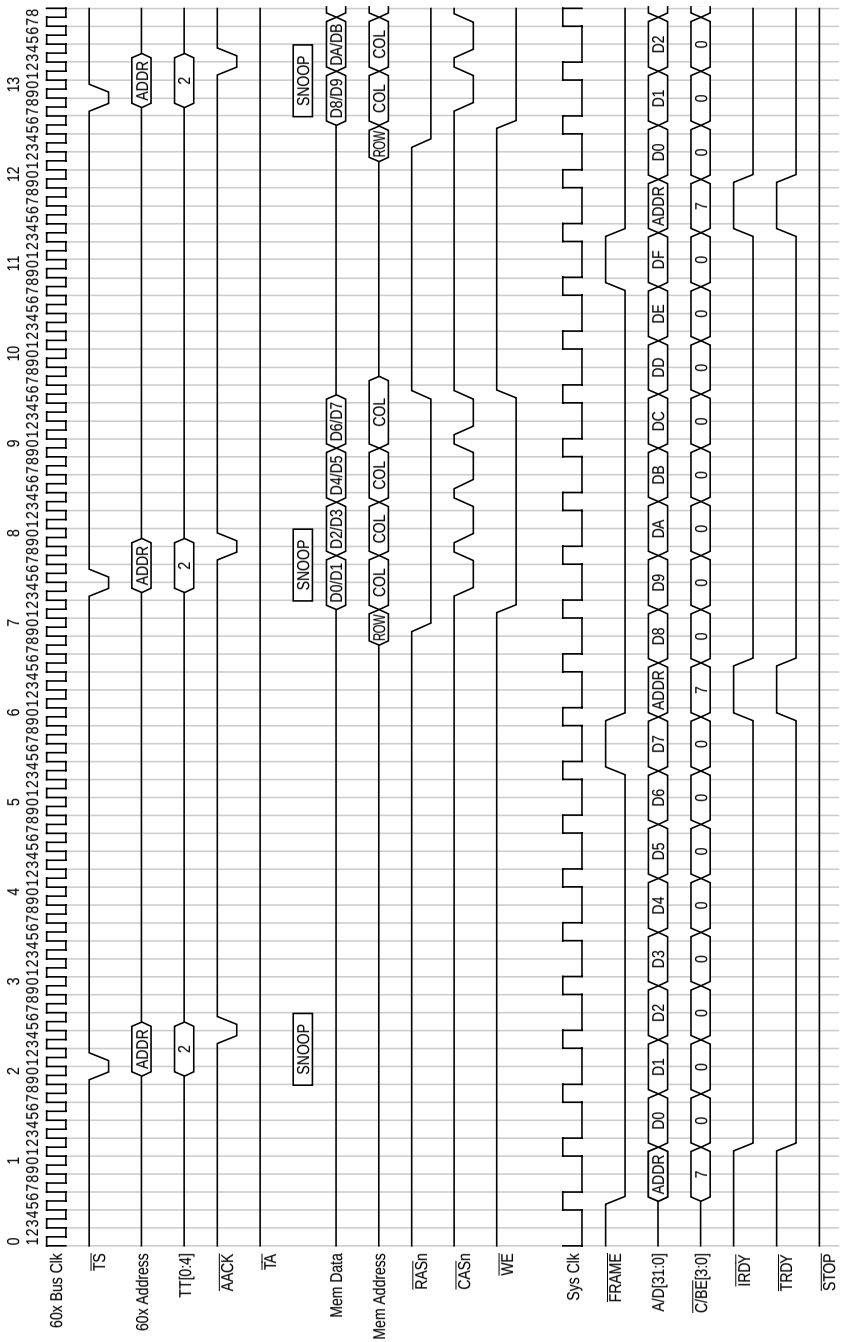

Figure 6-48. PCI Writes to DRAM

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6.4 ROM/Flash Interface Operation

For the ROM/Flash interface, the MPC8240 provides 21 address bits, two chip selects, one Flash output enable ($\overline{\text{FOE}}$), and one flash write enable ($\overline{\text{WE}}$).

Figure 6-49 displays a block diagram of the ROM interface.

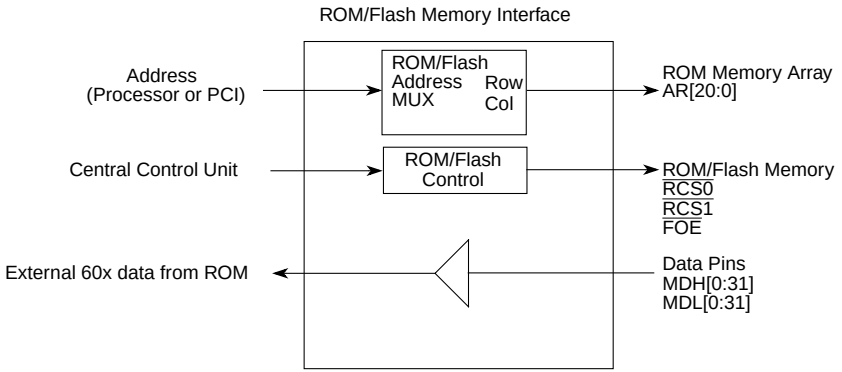
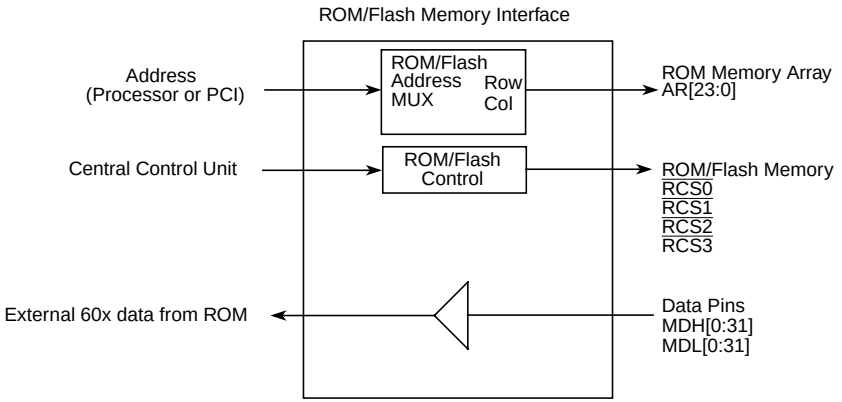


Figure 6-49. ROM Memory Interface Block Diagram

Figure 6-50 shows an example of a 16-Mbyte ROM system.



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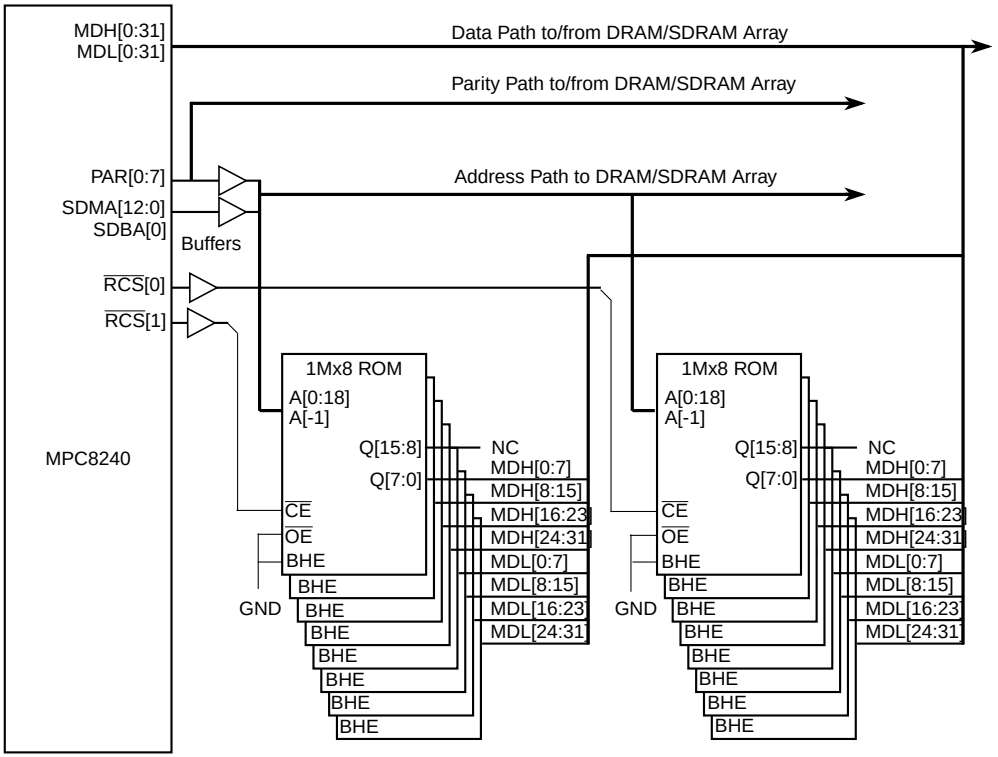

Address Signals (Outputs)	PAR								SDBA	SDMA										
	0	1	2	3	4	5	6	7	0	10	9	8	7	6	5	4	3	2	1	0
Logical Names	msb								AR											lsb
	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Notes:
1. The array of ROM memory devices are 8-Mbit (1M x 8 or 512K x 16) configured for 1M x 8 operation.
2. A[-1] is the lsb of the ROM memory devices.
3. BHE connected to GND enables A[-1] as an input and sets Q[15:8] to Hi-Z.
4. Q[7:0] of the ROM Memory devices are data outputs connected to MDH[0-31] and MDL[0:31]. MDH[0:7] is the most significant byte lane and MDL[24:31] is the least significant byte lane.
5. All $\overline{OE}$ and BHE signals are connected to GND.
6. $\overline{RCS}$0 is connected to all $\overline{CE}$ in Bank 0 (8 Mbytes) and $\overline{RCS}$1 is connected to all $\overline{CE}$ in Bank 1 (8 Mbytes).

Figure 6-50. 16-Mbyte ROM System Including Parity Paths to DRAM—64-Bit Mode

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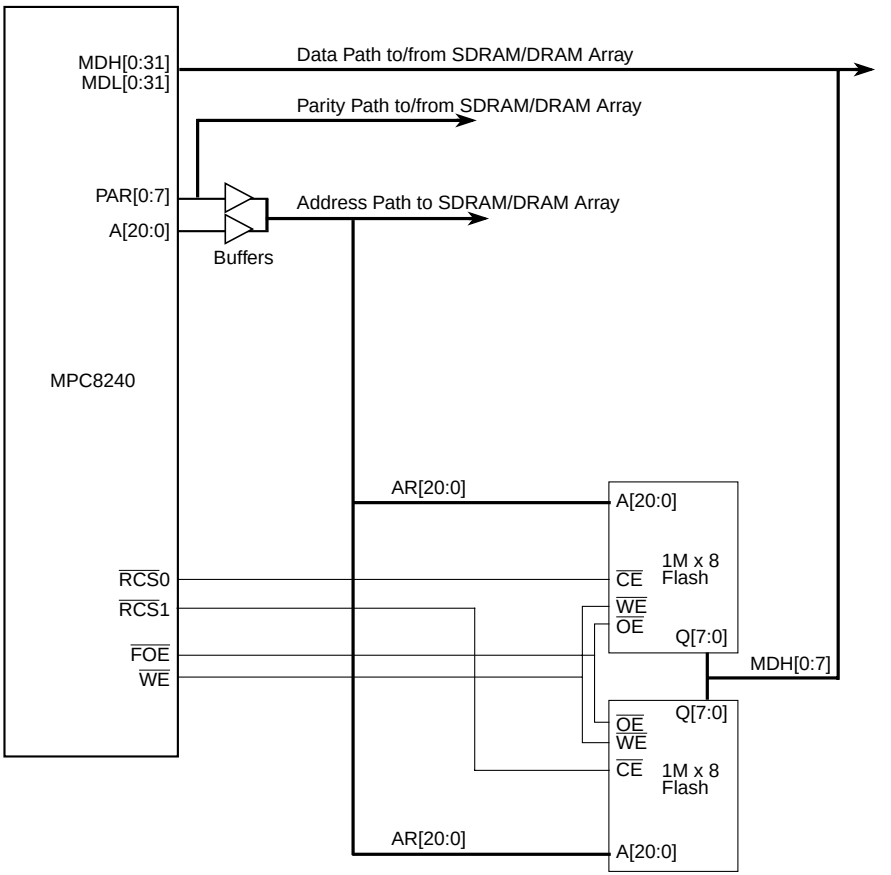
Figure 6-51 shows an example of a 2-Mbyte Flash system.



Address Signals (Outputs)	SDMA	PAR								SDBA	SDMA										
	12	0	1	2	3	4	5	6	7	0	10	9	8	7	6	5	4	3	2	1	0
Logical Names	AR[20:0]																				
	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Figure 6-51. 2-Mbyte Flash Memory System Including Parity Paths to DRAM—8-Bit Mode

The MPC8240 supports an 8-, 32-, or 64-bit data path to bank 0. A configuration signal ($\overline{\text{FOE}}$) sampled at reset, determines the bus width of the ROM or Flash device (8-bit, 32-bit, or 64-bit) in bank 0. The data bus width for ROM bank 1 is always 64 or 32 bits as determined by the configuration signal, MDL[0], sampled at reset.

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Note that the 8-bit data path requires external decode logic to select between the two devices. Also note that the 21st ROM/Flash address bit (SDMA12/SDBA1) is supported only for bank 0 using the 8-bit data path and for both banks using the 32-bit data path.

The extra address bit allows for up to 2 Mbytes of ROM/Flash space in bank 0 for the 8-bit data path configuration and up to 16 Mbytes of ROM/Flash space using both banks for the 32-bit data path configuration. For the 64-bit data path, 20 address bits allow for up to 8 Mbytes per bank for a total of 16 Mbytes using both banks. See Table 6-26.

Table 6-26. Reset Configurations of ROM/Flash Controller

MDL[0]	$\overline{\text{FOE}}$	Bank 0	Bank 1
0	0	32-bit interface 21 address bits 8 Meg space	32-bit interface 21 address bits 8 Meg space
1	0	64-bit interface 20 address bits 8 Meg space	64-bit interface 20 address bits 8 Meg space
0	1	8-bit interface 21 address bits 2 Meg space	32-bit interface 21 address bits 8 Meg space
1	1	8-bit interface 21 address bits 2 Meg space	64-bit interface 20 address bits 8 Meg space

When 64-bit SDRAM/DRAM is selected (MDL[0] =1), ROM/Flash only can be 8- or 64-bit (no 32-bit ROM/Flash).

For systems using the 8-bit interface to bank 0, the ROM/Flash device must be connected to the most-significant byte lane of the data bus MDH[0:7]. The MPC8240 performs byte-lane alignment for single-byte reads from ROM/Flash memory. The MPC8240 can also perform byte gathering for up to 8 bytes for ROM/Flash read operations. The data bytes are gathered and aligned within the MPC8240, and then forwarded to the local processor.

The 16-Mbyte ROM/Flash space is subdivided into two 8-Mbyte banks. Bank 0 (selected by $\overline{\text{RCS0}}$) is addressed from 0xFF80_0000 to 0xFFFF_FFFF. Bank 1 (selected by $\overline{\text{RCS1}}$) is addressed from 0xFF00_0000 to 0xFF7F_FFFF. Implementations that require less than 16 Mbytes may allocate the required ROM/Flash to one or both banks.

For example, an implementation that requires only 4 Mbytes of ROM/Flash could locate the ROM/Flash entirely within bank 0 at addresses 0xFFC0_0000–0xFFFF_FFFF. Alternately, the ROM/Flash could be split across both banks with 2 Mbytes in bank 0 at 0xFFE0_0000–0xFFFF_FFFF and 2 Mbytes in bank 1 at 0xFF60_0000–0xFF7F_FFFF. Any system ROM space that is not physically implemented within a bank is aliased to any physical device within that bank.

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The MPC8240 can be configured to support ROM/Flash devices located on the memory bus or on the PCI bus. The $\overline{RCS0}$ signal is sampled at reset to determine the location of ROM/Flash. If the system ROM space is mapped to the PCI bus, the MPC8240 directs all system ROM accesses to the PCI bus.

The MPC8240 also supports splitting the system ROM space between PCI and the memory bus. The entire ROM space is mapped to the PCI space, and then, by setting the configuration parameter PICR2[CF_FF0_LOCAL], the lower half of the ROM space (0xFF00_0000–0xFF7F_FFFF) is remapped onto the memory bus. This allows the system to have the upper half of ROM space on the PCI bus for boot firmware and the lower half of the ROM space on the memory bus for performance critical firmware. The ROM/Flash on the memory bus is selected by $\overline{RCS1}$. The data path width (32 or 64 bits) is determined by the state of the $\overline{FOE}$ and MDL[0] signals, at power on reset, as shown in Table 6-26.

6.4.1 ROM/Flash Address Multiplexing

System software must configure the MPC8240 at power-on-reset to multiplex appropriately the row and column address bits for each bank. Address multiplexing for the 8-bit mode occurs according to the interface configuration settings as shown in Figure 6-52.

MPC8240 Output Signals 8-bit Mode	Physical Address																								
	0–10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
SDMA												10	9	8	7	6	5	4	3	2	1	0
SDBA											0											
PAR			0	1	2	3	4	5	6	7												
SDMA		12																				
Logical Names																						
AR		20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0

Figure 6-52. ROM/Flash Address Multiplexing—8-Bit Mode

Address multiplexing for the 32-bit mode occurs according to the interface configuration settings as shown in Figure 6-53.

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MPC8240 Output Signals 32-bit Mode	Physical Address																													
	0–8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
SDMA												10	9	8	7	6	5	4	3	2	1	0		
SDBA											0													
PAR			0	1	2	3	4	5	6	7														
SDMA		12																						
Logical Names																								
AR		20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0		

Figure 6-53. ROM/Flash Address Multiplexing—32-Bit Mode

Address multiplexing for the 64-bit mode occurs according to the interface configuration settings as shown in Figure 6-54.

MPC8240 Output Signals 64-bit Mode	Physical Address																													
	0–8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
SDMA											10	9	8	7	6	5	4	3	2	1	0			
SDBA										0														
PAR		0	1	2	3	4	5	6	7															
Logical Names																								
AR		19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0			

Figure 6-54. ROM/Flash Address Multiplexing—64-Bit Mode

6.4.2 64 or 32-Bit ROM/Flash Interface Timing

The MPC8240 provides 20 address bits with which to access 8 Mbytes of external 64-bit ROM and 21 address bits with which to access 8 Mbytes of external 32-bit ROM. In addition, two ROM chip selects ($\overline{RCS0}$, $\overline{RCS1}$) allow addressing of ROM memories of up to 16 Mbytes.

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For 64-bit ROMs, the eight most significant address bits are provided as an alternate function on the MPC8240's parity signals, PAR[0:7] (AR[19:12]), with PAR[0] (AR[19]) representing the most significant address bit. The remaining 12 low-order address bits are provided on the MPC8240's SDBA0 (AR[11]) and SDMA[10:0] (AR[10:0]) signals with SDMA[0] (AR[0]) representing the least significant bit.

For 32-bit ROMs, the least significant 20 address bits are identical to those previously described for 64-bit ROMs. However, a 21st address bit, SDMA12/SDBA1 (AR[20]), is added as the new most significant address bit. Refer to Table 6-2 for the memory address signal mappings.

The MPC8240's two ROM chip select outputs are decoded from the memory address and can be used as bank selects. The MPC8240 can access 16 Mbytes of ROM in systems that have a 64-bit memory bus (8 Mbytes each in bank $\overline{\text{RSC0}}$ and bank $\overline{\text{RSC1}}$). In this mode, bank select $\overline{\text{RCS0}}$ decodes addresses 0xFF80_0000–FFFF_FFFF, and $\overline{\text{RCS1}}$ decodes addresses 0xFF00_0000–FF7F_FFFF.

Implementations requiring less than 16 Mbytes of ROM may allocate the required ROM to one or both banks. As an example, a 4-Mbyte implementation can place the ROM entirely within the range of $\overline{\text{RCS0}}$, (at 0xFFC0_0000–FFFF_FFFF), or can split the ROM between $\overline{\text{RCS1}}$ and $\overline{\text{RCS0}}$, (at 0xFF60_0000–FF7F_FFFF and 0xFFE0_0000–FFFF_FFFF).

The MPC8240 can access 16 Mbytes of ROM in systems that have a 32-bit memory bus (8 Mbytes in each bank). In this mode, bank select $\overline{\text{RCS0}}$ decodes addresses 0xFF80_0000–FFFF_FFFF, and $\overline{\text{RCS1}}$ decodes addresses 0xFF00_0000–FF7F_FFFF. As mentioned previously, implementations that require less than 8 Mbytes of ROM may allocate the required ROM to one or both banks.

The MPC8240 provides programmable access timing for ROM so that systems of various clock frequencies can be implemented. The MPC8240 can also be configured to take advantage of burst (or nibble) mode access time improvements which are available with some ROMs. The programmable parameters for ROM access have granularity of 1 clock cycle, and are named ROMFAL[0–4] and ROMNAL[0–3] in memory control configuration register 1 (MCCR1).

ROMFAL represents wait states in the access time for non-bursting ROMs, and also measures wait states for the first data beat from bursting ROMs. The access time is ROMFAL + 3 clock cycles for 64- or 32-bit read accesses and ROMFAL + 2 clock cycles for 8-bit read accesses. Additionally, if the memory interface is configured in the registered mode (MCCR4[REGISTERED] = 1], one more clock cycle is incurred in these read access times. All write accesses takes ROMFAL + 2 clock cycles.

ROMNAL represents wait states in access time for nibble (or burst) mode accesses to bursting ROMs. The nibble mode access time is ROMNAL + 2 clock cycles. To enable the burst mode timing capability, the memory control configuration register 1 (MCCR1) BURST bit must be set by boot code.

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ROMFAL and ROMNAL are configured to their maximum value at reset in order to accommodate initial boot code fetches. The MCCR1[BURST] configuration bit is cleared at reset. ROM interface timing configuration, and use of the ROMFAL and ROMNAL parameters, are shown in Figure 6-55, Figure 6-56, and Figure 6-57.

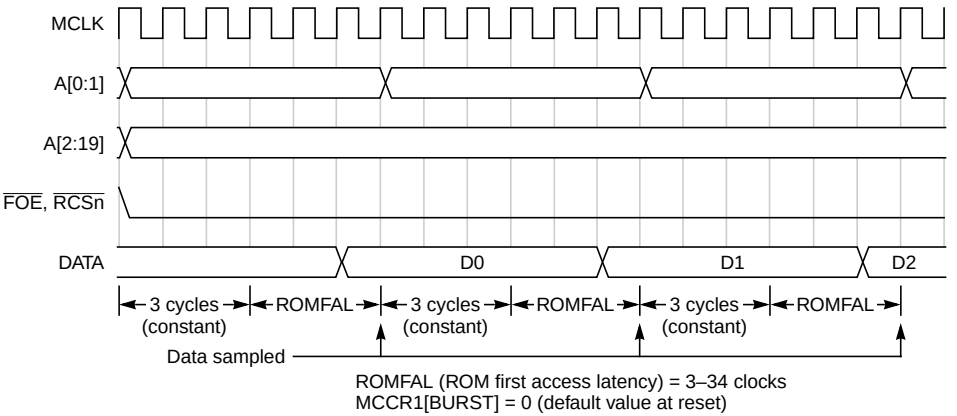

Figure 6-55. Read Access Timing for Non-Burst ROM/Flash Devices in 32- or 64-Bit Mode

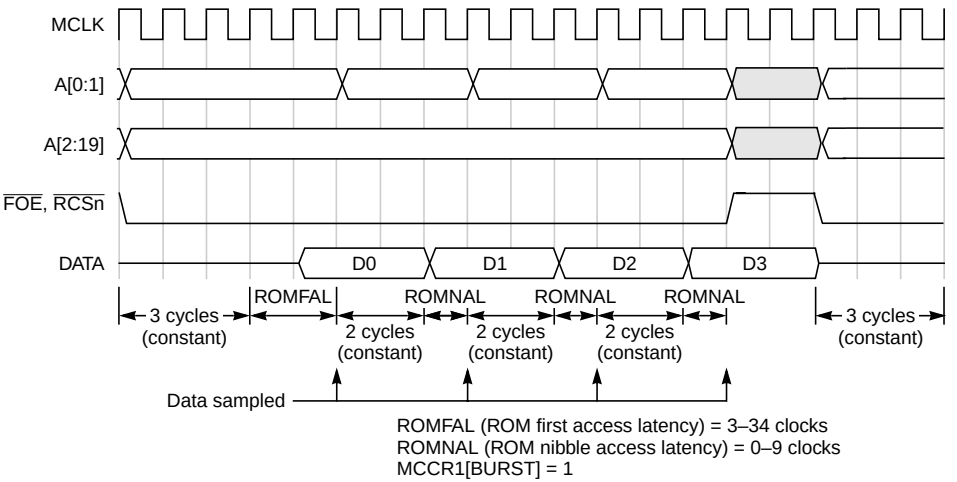

Figure 6-56. Read Access Timing (Cache Block) for Burst ROM/Flash Devices in 64-Bit Mode

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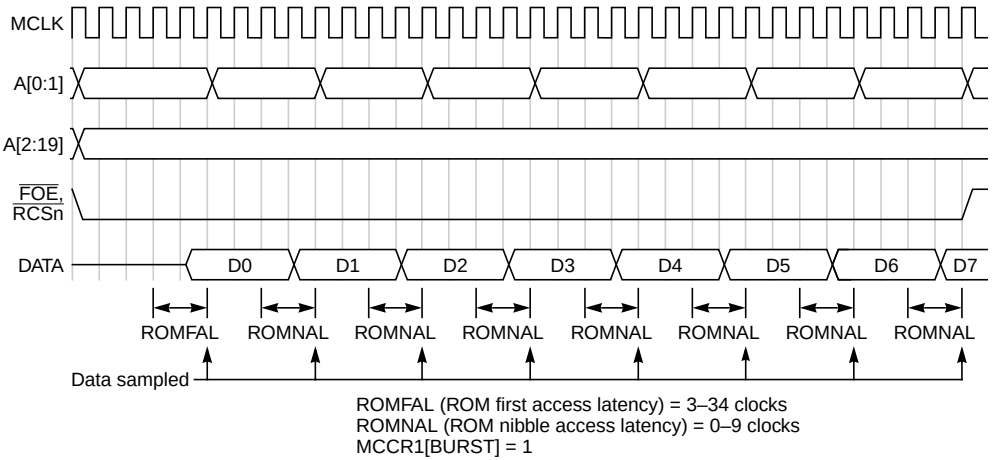

Figure 6-57. Read Access Timing (Cache Block) for Burst ROM/Flash Devices in 32-Bit Mode

6.4.3 8-Bit ROM/Flash Interface Timing

The MPC8240 provides 21 address bits for accessing 2 Mbytes of external 8-bit ROM/Flash memory. The most significant address bit is SDMA12/SDBA1. The next eight most significant address bits are provided as an alternate function on the MPC8240's parity signals, PAR[0:7] (AR[19:12]). The remaining 12 low-order address bits are provided on the MPC8240's SDBA[0] (AR[11]) and SDMA[10:0] (AR[10:0]) signals with SDMA[0] (AR[0]) as the least significant bit. Refer to Table 6-2 for the memory address signal mappings.

The MPC8240 also provides a chip select ($\overline{\text{RCS0}}$), output enable ($\overline{\text{FOE}}$), and write enable ($\overline{\text{WE}}$) to facilitate both read and write accesses to Flash memory. The MPC8240 supports x8 organizations of Flash memory up to a total space of 2 Mbytes. Chip select $\overline{\text{RCS0}}$ is decoded from the memory address, and is active for addresses in the range 0xFF80_0000–FFFF_FFFF for Flash.

The MPC8240 performs byte-lane alignment for byte reads from Flash (x8) boot memory. The MPC8240 gathers bytes for half-word, word, and double-word reads from Flash (x8) boot memory.

The MPC8240 provides programmable timing for read and write access to Flash, with granularity of 1 system clock cycle. ROMFAL[0–4] is used to determine read and write cycle wait states. ROMNAL[0–3] is used to determine write recovery time. Refer to Figure 6-58 for further information.

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The following figures illustrate the 8-bit ROM/Flash interface timing for various read accesses. Figure 6-58 shows a single-byte read access. Figure 6-59 shows a two-byte (half-word) read access. Word and double-word accesses require using the cache-line read access timing shown in Figure 6-60.

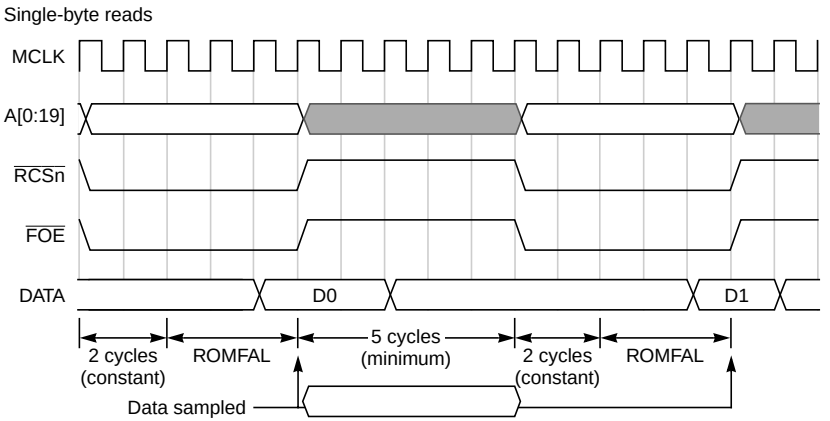

Figure 6-58. 8-Bit ROM/Flash Interface—Single-Byte Read Timing

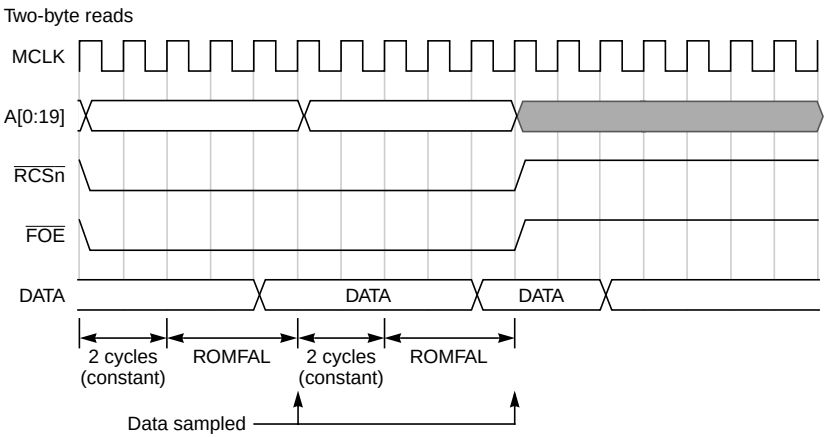

Figure 6-59. 8-Bit ROM/Flash Interface—Two-Byte Read Timing

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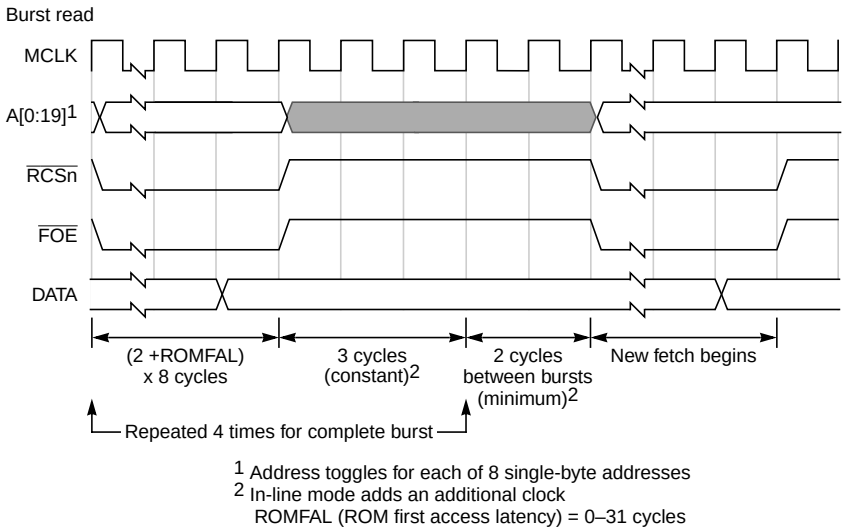

Figure 6-60. 8-Bit ROM/Flash Interface—Cache-Line Read Timing

6.4.4 ROM/Flash Interface Write Operations

PICR1[FLASH_WR_EN] must be set for write operations to Flash memory. FLASH_WR_EN controls whether write operations to Flash memory are allowed. FLASH_WR_EN is cleared at reset to disable write operations to Flash memory.

Writes to Flash can be locked out by setting PCIR2 [FLASH_WR_LOCKOUT]. When this bit is set, the MPC8240 disables writing to Flash memory, even if FLASH_WR_EN is set. Once set, the FLASH_WR_LOCKOUT parameter can be cleared only by a hard reset.

If the system attempts to write to read-only devices in a bank, bus contention may occur. This is because the write data is driven onto the data bus when the read-only device is also trying to drive its data onto the data bus. This situation can be avoided by disabling writes to the system ROM space using FLASH_WR_EN or FLASH_WR_LOCKOUT or by connecting the Flash output enable ($\overline{\text{FOE}}$) signal to the output enable on the read-only device.

System logic is responsible for multiplexing the required high voltages to the Flash memory for write operations.

The MPC8240 accommodates only single-beat writes to Flash memory. If an attempt is made to write to Flash with a data size other than the full data path size, the MPC8240 does not report an error. Thus, if software is writing to Flash, the write operations should be sized to the data path width (8, 32 or 64 bits) since there is only a single write enable ($\overline{\text{WE}}$) strobe available.

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6.4.5 ROM/Flash Interface Write Timing

The parameter MCCR1[ROMNAL] controls the Flash memory write recovery time (that is, the number of cycles between write pulse assertions). The actual recovery cycle count is four cycles more than the value specified in ROMNAL. For example, when ROMNAL = 0b0000, the write recovery time is 4 clock cycles; when ROMNAL = 0b0001, the write recovery time is 5 clock cycles; when ROMNAL = 0b0010, the write recovery time is 6 clock cycles; and so on. ROMNAL is set to the maximum value at reset. To improve performance, initialization software should program a more appropriate value for the device being used.

Figure 6-61 shows the write access timing of the Flash interface.

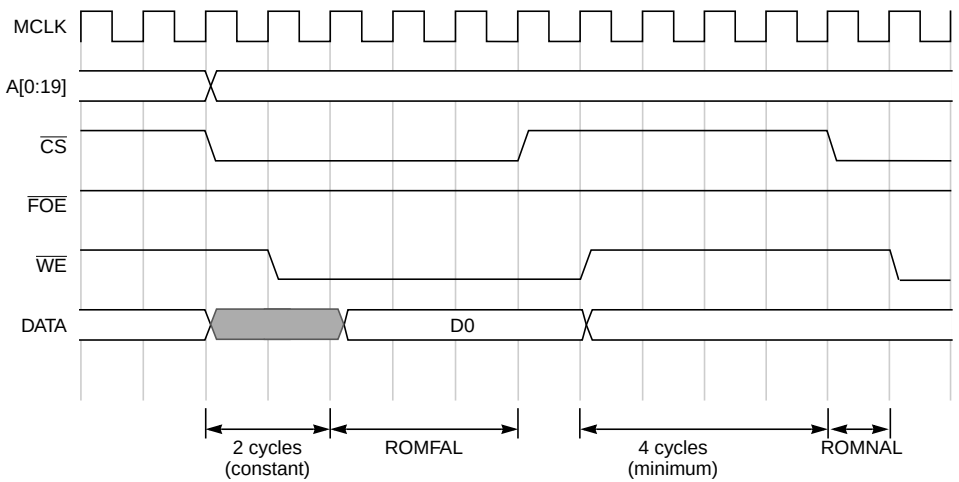

Figure 6-61. 8-, 32-, or 64-Bit Flash Write Access Timing

6.4.6 PCI-to-ROM/Port X Transaction Example

The figures in this section provide examples of signal timing for PCI-to-ROM/Port X transactions. Figure 6-62 shows a series of PCI reads from ROM/Port X(64-Bit). Figure 6-63 shows a series of PCI reads from ROM/Port X (8-Bit).

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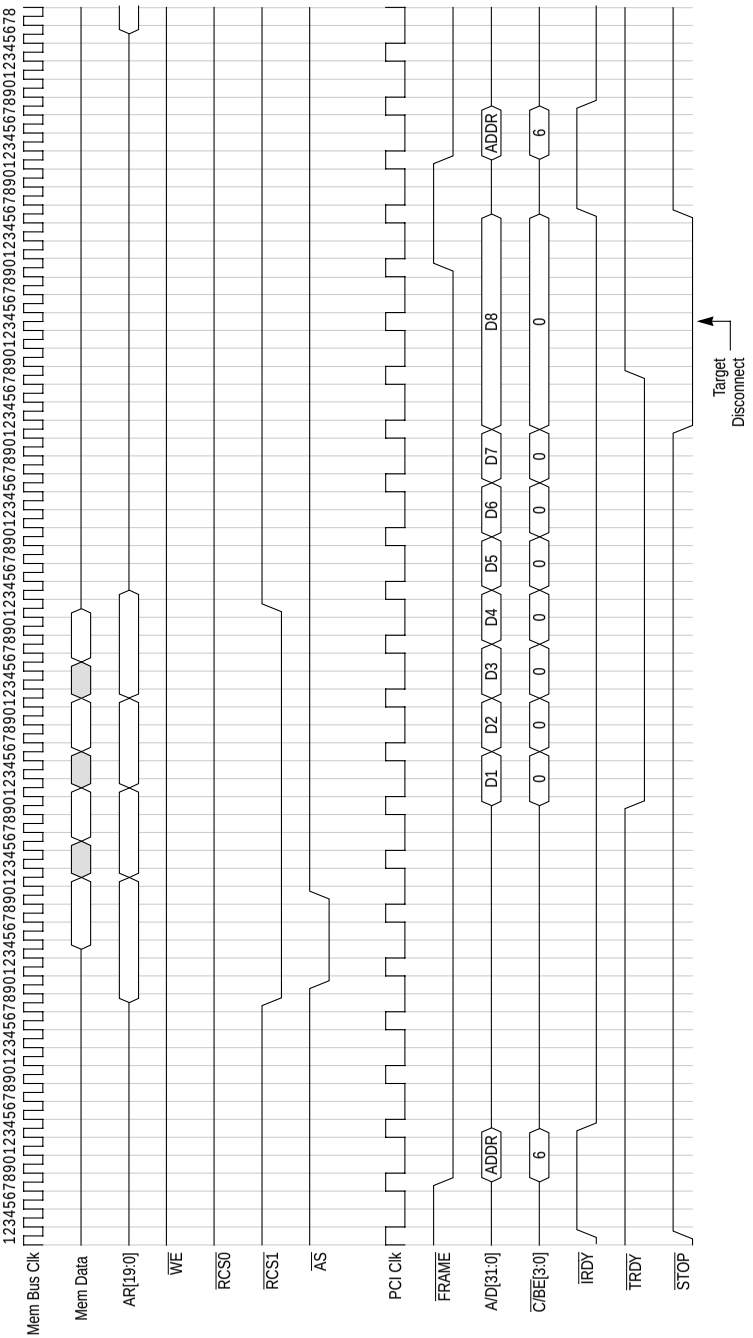

Figure 6-62. PCI Read from ROM/Port X 64-Bit

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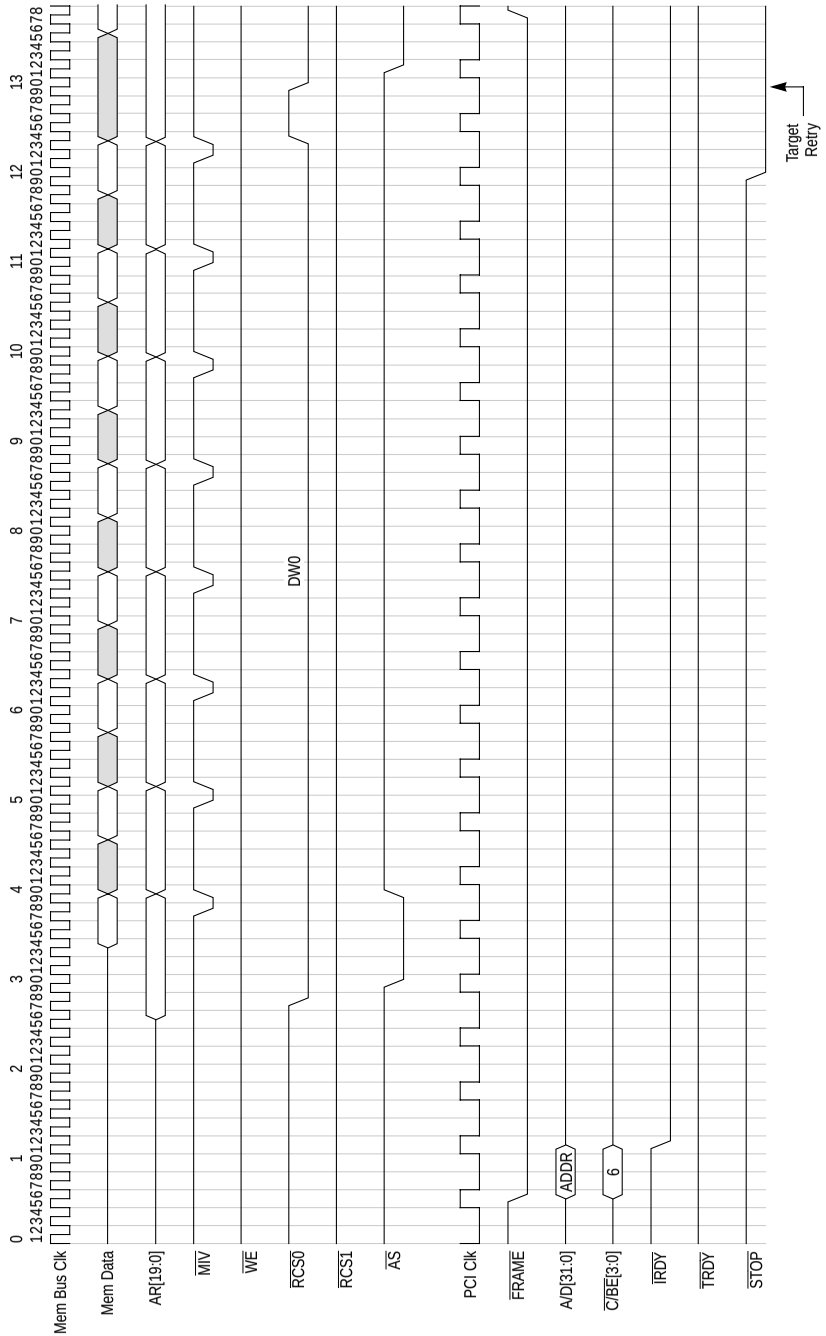

Figure 6-63. PCI Read from ROM/Port X 8-Bit (Part 1 of 4)

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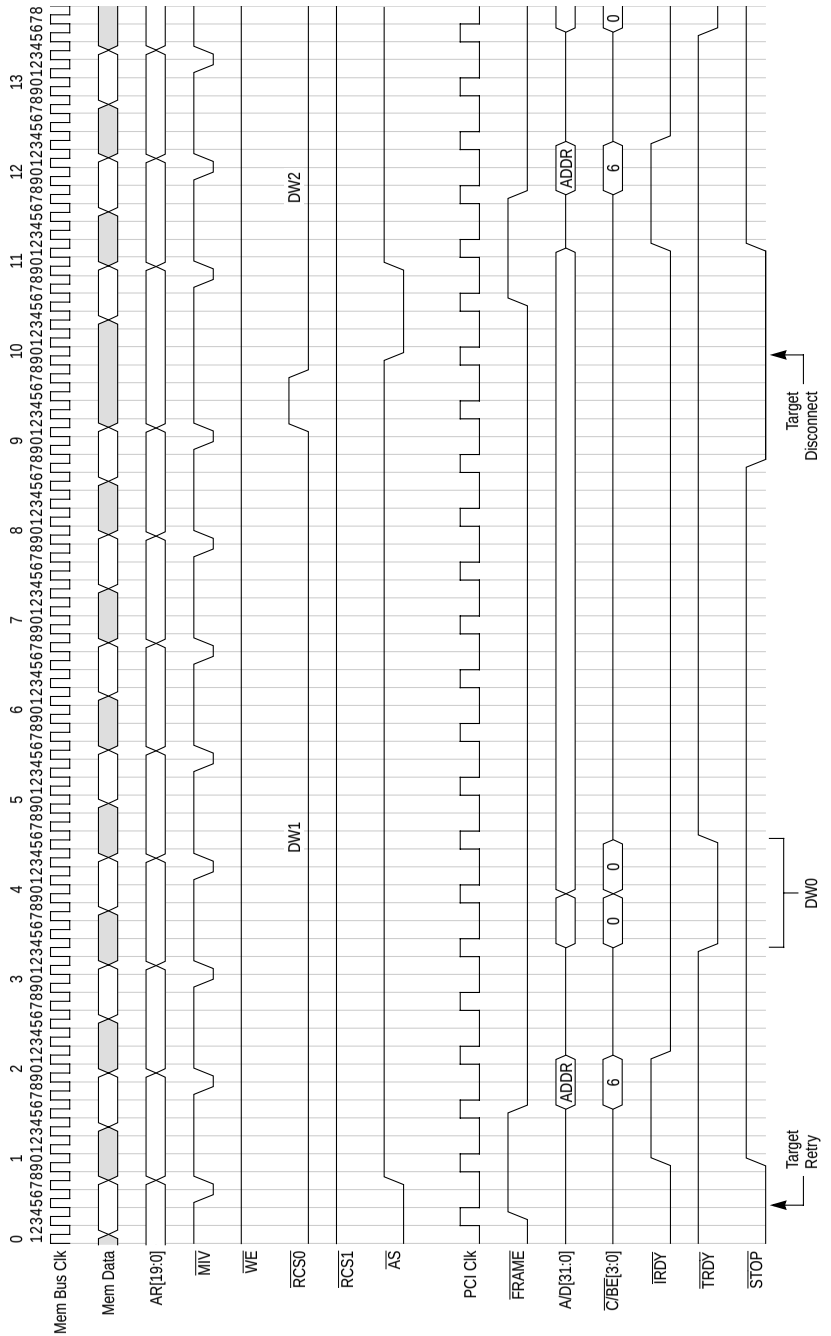

Figure 6-63. (Continued) PCI Reads from ROM/Port X 8-Bit (Part 2 of 4)

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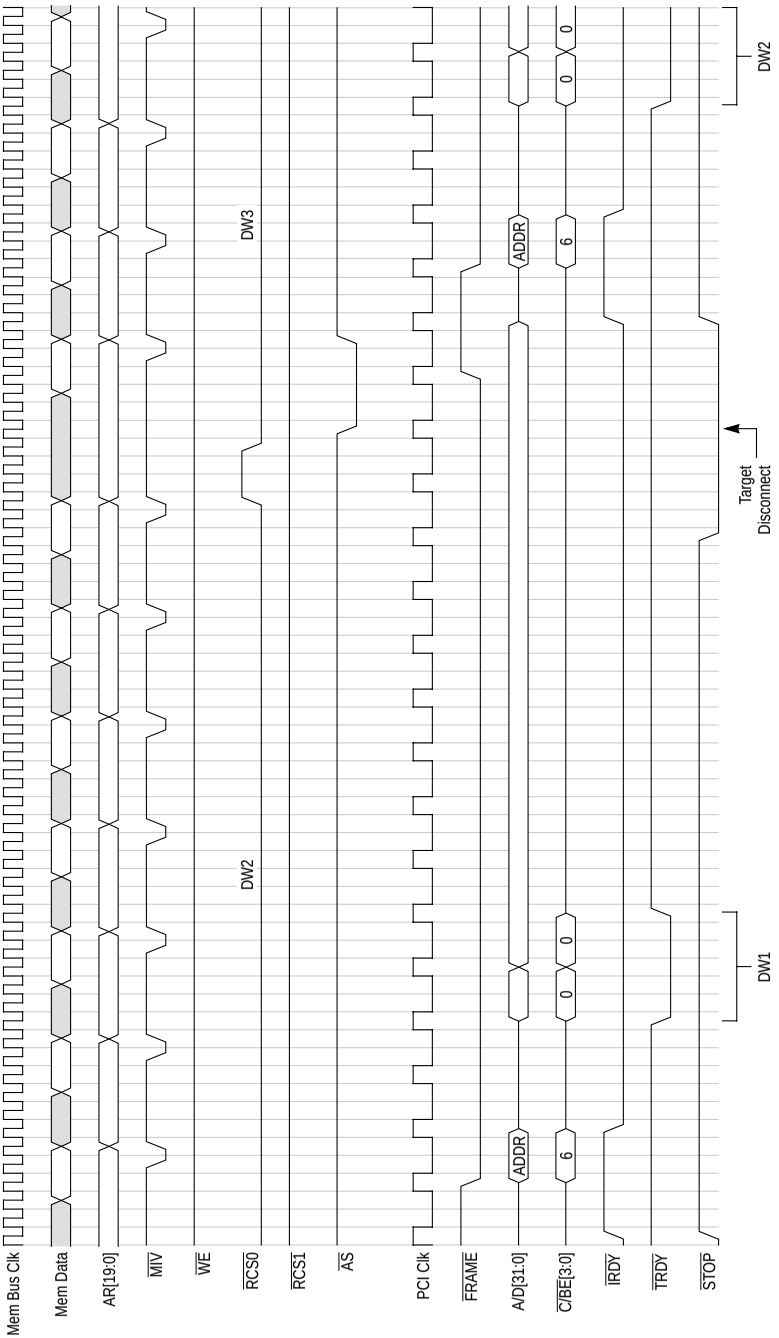

Figure 6-63. (Continued) PCI Reads from ROM/Port X 8-Bit (Part 3 of 4)

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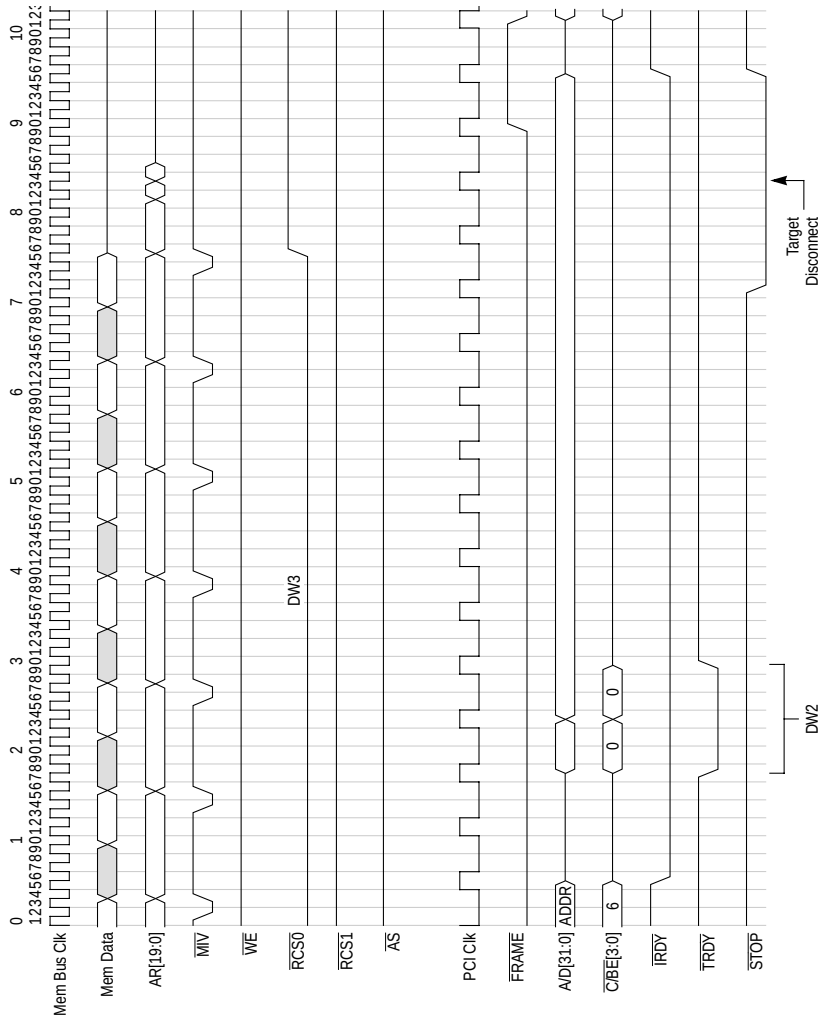

Figure 6-63. (Continued) PCI Reads from ROM/Port X 8-Bit (Part 4 of 4)

6.4.7 Port X Interface

The MPC8240's memory interface is flexible enough to allow the system designer to connect other non-memory devices to it. This functionality is typically called Port X. By sharing the ROM/Flash interface capabilities with general purpose I/O devices it is possible to configure a wide range of devices with the MPC8240. Note that the Port X interface shares the MPC8240 ROM/Flash state machine and so the timing configurations used for ROM/Flash also apply to Port X (that is, a system cannot set up different timings for ROM/Flash and Port X). Figure 6-64 shows a block diagram of the Port X Peripheral Interface.

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Figure 6-65 and Figure 6-66 show two examples of Port X implementations. Adding miscellaneous devices to the MPC8240 memory bus limits the total memory devices or maximum bus speed due to signal loading constraints and address space limitations.

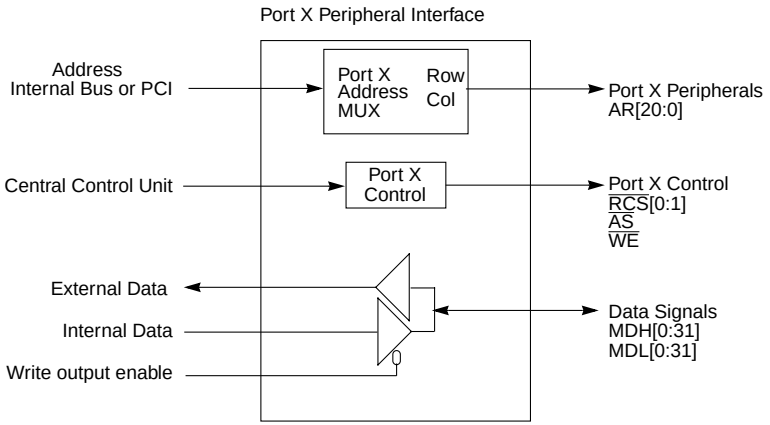

Figure 6-64. Port X Peripheral Interface Block Diagram

Because the MPC8240 shares the Port X interface with the Flash interface, only single-beat writes to Port X are supported. Therefore, care must be taken if the Port X memory space is marked as cacheable (as burst writes for cache block castouts are not supported). Additionally, writes of data for a size other than the full memory width may be desired (for example, 16-bit write to a Port X device on a memory interface configured as 64-bit).The MPC8240 allows these transactions and does not report an error.

For Port X accesses, data is provided on the data bus as with a memory device. Address and control are provided on the address signals. The $\overline{AS}$ signal's falling and rising edges are programmable to provide a latch strobe or edge reference to allow the external device to latch the data, address, or control signals from the memory interface signals. $\overline{AS}$ is driven active for all accesses to the ROM/Flash address space (0xFF00_0000–0xFFFF_ FFFF). This allows for Port X devices to share the address space with ROM devices.

The timing of the $\overline{AS}$ signal is controlled by two programmable parameters in MCCR2, ASFALL[0–3] and ASRISE[0–3]. See Section 4.10, "Memory Control Configuration Registers," for more information on MCCR2. ASFALL controls when the $\overline{AS}$ signal transitions from a logic 1 to a logic 0 in relation to the $\overline{RCS}$[0–1] transition from logic 1 to logic 0. If ASFALL is set to 0b0000, the $\overline{AS}$ is asserted on the same clock cycle as the $\overline{RCS}$[0–1]. A value greater than 0b0000 adds that number of clock cycles to the difference between $\overline{AS}$ and $\overline{RCS}$[0–1]. For example, an ASFALL value of 0b0011 means that the $\overline{AS}$ asserts 3 clock cycles after $\overline{RCS}$[0–1].

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The ASRISE parameter controls when $\overline{AS}$ negates. For example, an ASRISE value of 0b0100 means that $\overline{AS}$ negates 4 clock cycles after it asserts. Setting ASRISE = 0 effectively disables $\overline{AS}$ and causes it to remain negated. At reset, both ASRISE and ASFALL are initialized to 0. Example timing for Port X accesses is shown in Figure 6-67 and Figure 6-68.

Due to restrictions in the ROM and Flash controllers, the ASFALL and ASRISE parameters should be programmed as ASRISE + ASFALL ≤ ROMFAL + 7 if the ROM interface is programmed to support 8-bit data bus mode for $\overline{RCS0}$, (DBUS_SIZE = x1). Otherwise ASFALL and ASRISE should be programmed as ASRISE + ASFALL ≤ ROMFAL + 4. Note that $\overline{AS}$ may not negate between back-to-back Port X transfers if ASFALL is set to 0x0, and ASRISE is set to the maximum allowed value.

The ROM and Flash controllers are capable of multiple-beat read operations (that is, multiple data tenures for one address tenure). Note, however, that if a Port X device is accessed with a multiple-beat read operation, $\overline{AS}$ asserts and negates only once and not multiple times after $\overline{RCS}$[0 or 1] asserts.

The following minimum negation times apply for $\overline{RCS}$[0–1] in between Port X transactions:

- 5 clocks (8-bit data bus reads and all writes); typically greater due to processor and CCU activity
- 2 clocks (32- or 64-bit data bus reads); typically greater due to processor and CCU activity

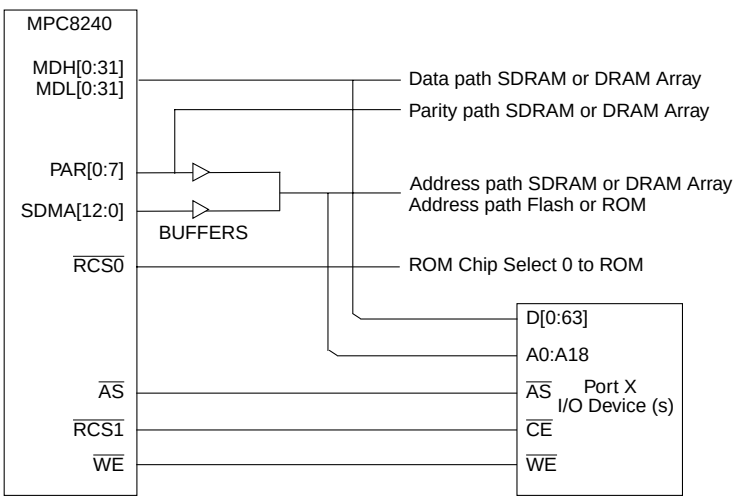

Figure 6-65. Example of Port X Peripheral Connected to the MPC8240

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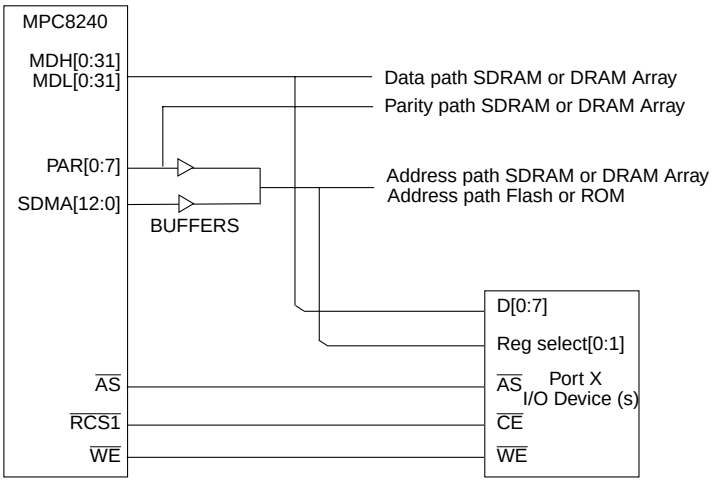

Figure 6-66. Example of Port X Peripheral Connected to the MPC8240

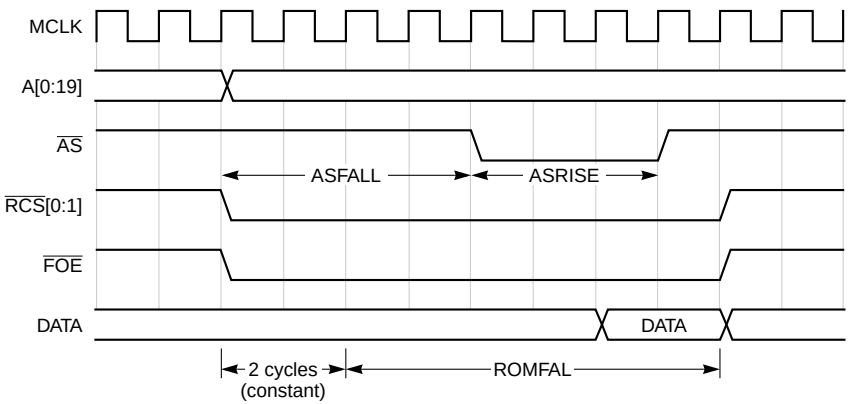

Figure 6-67. Port X Example Read Access Timing

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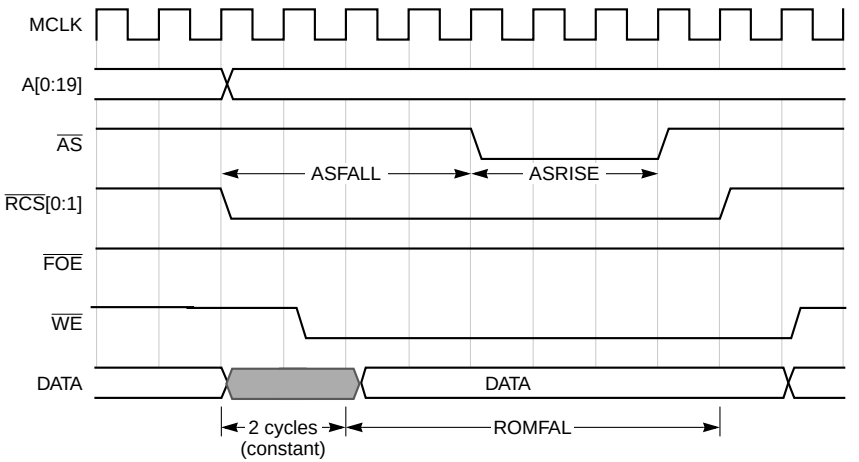

Figure 6-68. Port X Example Write Access Timing

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Chapter 7
PCI Bus Interface

The MPC8240's PCI interface complies with the *PCI Local Bus Specification*, rev 2.1. It is beyond the scope of this manual to document the intricacies of the PCI bus. This chapter provides a rudimentary description of the PCI bus operations. The specific emphasis is directed at how the MPC8240 implements the PCI bus. Designers of systems incorporating PCI devices should refer to the *PCI Local Bus Specification*, rev 2.1 for a thorough description of the PCI local bus.

NOTE:

Much of the available PCI literature refers to a 16-bit quantity as a word and a 32-bit quantity as a double word. Since this is inconsistent with the terminology in this manual, the terms 'word' and 'double word' are not used in this chapter. Instead, the number of bits or bytes indicates the exact quantity.

7.1 PCI Interface Overview

The PCI interface connects the processor core and local memory to the PCI bus to which I/O components are connected. The PCI bus uses a 32-bit multiplexed, address/data bus, plus various control and error signals. The PCI interface supports address and data parity with error checking and reporting. Internal buffers are provided for operations between the PCI bus and the processor core or local memory. Processor read and write operations each have a 32-byte buffer, and memory operations have two 32-byte read buffers, and two 32-byte write buffers. Additionally, PCI accesses to local memory must share access to the processor/memory data bus with other MPC8240 resources (for example, the DMA controller). See Chapter 12, "Central Control Unit," for more information on both the internal read and write buffers and the arbitration priorities for the shared processor/memory data bus.

The PCI interface of the MPC8240 functions both as a master (initiator) and a target device. Internally, the PCI interface of the MPC8240 is controlled by two state machines (one for master and one for target operation) running independently of each other. This allows the MPC8240 to handle two separate PCI transactions simultaneously. For example, if the MPC8240, as an initiator, is trying to run a burst-write to a PCI device, it may get disconnected before finishing the transaction. If another PCI device is granted the PCI bus and requests a burst-read from local memory, the MPC8240, as a target, can accept the burst-read transfer. When the MPC8240 is granted mastership of the PCI bus, the burst-write transaction continues.

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As an initiator, the MPC8240 supports read and write operations to the PCI memory space, the PCI I/O space, and the 256-byte PCI configuration space. As an initiator, the MPC8240 also supports generating PCI special-cycle and interrupt-acknowledge transactions. As a target, the MPC8240 supports read and write operations to local memory and read and write operations to the internal PCI-accessible configuration registers.

The MPC8240 can function as either a PCI host bridge referred to as 'host mode' or a peripheral device on the PCI bus referred to as 'agent mode'. Note that agent mode is supported only for address map B. See Section 7.7, "PCI Host and Agent Modes," for more information.

All of the PCI-accessible configuration registers in the MPC8240 can be programmed from the PCI bus. However, the PICRs, MICRs, and other configuration registers are not accessible from the PCI bus and must be programmed by the processor core. See Section 7.7.2, "Accessing the MPC8240 Configuration Space," for more information.

The PCI interface provides bus arbitration for the MPC8240 and up to five other PCI bus masters. The arbitration algorithm is a programmable two-level round-robin priority selector. The on-chip PCI arbiter can operate in both host and agent modes or it can be disabled to allow for an external PCI arbiter.

The MPC8240 also provides an address translation mechanism to map inbound PCI to local memory accesses and outbound processor core to PCI accesses. Address translation is required when the MPC8240 is operating in agent mode. Address translation is not supported in host mode. See Section 7.7.4, "PCI Address Translation Support," for more information.

The interface can be programmed for either little-endian or big-endian formatted data, and provides data swapping, byte enable swapping, and address translation in hardware. See Appendix B, "Bit and Byte Ordering," for more information on the bi-endian features of the MPC8240.

7.1.1 The MPC8240 as a PCI Initiator

Upon detecting a processor-to-PCI transaction, the MPC8240 requests the use of the PCI bus. For processor-to-PCI bus write operations, the MPC8240 requests mastership of the PCI bus when the processor completes the write operation on the internal peripheral logic bus. For processor-to-PCI read operations, the MPC8240 requests mastership of the PCI bus when it decodes that the access is for PCI address space.

Once granted, the MPC8240 drives the 32-bit PCI address (AD[31:0]) and the bus command ($\overline{C/BE}$[3:0]) signals. The master interface supports reads and writes of up to 32 bytes without inserting master-initiated wait states.

The master part of the interface can initiate master-abort cycles, recognizes target-abort, target-retry, and target-disconnect cycles, and supports various device selection timings. The master interface does not run fast back-to-back or exclusive accesses.

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7.1.2 The MPC8240 as a PCI Target

As a target, upon detection of a PCI address phase the MPC8240 decodes the address and bus command to determine if the transaction is for local memory. If the transaction is destined for local memory, the target interface latches the address, decodes the PCI bus command, and forwards them to an internal control unit. On writes to local memory, data is forwarded along with the byte enables to the internal control unit. On reads, four bytes of data are provided to the PCI bus and the byte enables determine which byte lanes contain meaningful data.

The target interface of the MPC8240 can issue target-abort, target-retry, and target-disconnect cycles. The target interface supports fast back-to-back transactions and exclusive accesses using the PCI lock protocol. The target interface uses the fastest device selection timing.

The MPC8240 supports data streaming to and from local memory. This means that the MPC8240 can accept or provide data to or from local memory as long as the internal PCI-to-system-memory-write-buffers (PCMWBs) or PCI-to-system-memory-read buffers (PCMRBs) are not filled. For more information about the internal buffers of the MPC8240, see Chapter 12, “Central Control Unit.”

There are two 32-byte PCMWBs and while one is filled from the PCI master, the other is flushed to local memory. Some memory operations (such as refresh) can stall the flushing of the PCMWBs. In that case, the MPC8240 issues a target disconnect when there is no more space remaining in the PCMWBs.

Burst reads from local memory are accepted with wait states inserted depending upon the timing of local memory devices. The MPC8240 has two 32-byte PCMRBs and can provide continuous data to a PCI master by flushing one PCMRB to the PCI master while the other is being filled from local memory.

7.1.3 PCI Signal Output Hold Timing

In order to meet minimum output hold specifications relative to PCI_SYNC_IN for both 33 MHz and 66 MHz PCI systems, the MPC8240 has a programmable output hold delay for PCI signals. The initial value of the output hold delay is determined by the values on the $\overline{\text{MCP}}$ and CKE power-on reset configuration signals (see Section 2.4, “Configuration Signals Sampled at Reset”). Further output hold delay values are available by programming the PCI_HOLD_DEL value of the PMCR2 configuration register. Refer to Section 4.3.2, “Power Management Configuration Register 2 (PMCR2)—Offset 0x72,” and the *MPC8240 Hardware Specification* for more information on these values and signal timing.

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7.2 PCI Bus Arbitration

PCI bus arbitration is access-based. Bus masters must arbitrate for each access performed on the bus. The PCI bus uses a central arbitration scheme where each master has its own unique request ($\overline{\text{REQ}}$) output and grant ($\overline{\text{GNT}}$) input signal. A simple request-grant handshake is used to gain access to the bus. Arbitration for the bus occurs during the previous access so that no PCI bus cycles are consumed due to arbitration (except when the bus is idle).

The MPC8240 provides bus arbitration logic for the MPC8240 and up to five other PCI bus masters. The on-chip PCI arbiter is independent of host or agent mode. The on-chip PCI arbiter functions in both host and agent modes, or it can be disabled to allow for an external PCI arbiter.

A configuration signal (MAA2) sampled at the negation of the reset signal ($\overline{\text{HRST\_CTRL}}$) determines if the on-chip PCI arbiter is enabled (low) or disabled (high). The on-chip PCI arbiter can also be enabled or disabled by programming bit 15 of the PCI arbitration control register (PACR). Note that the sense of bit 15 corresponds to the inverse of the polarity of the configuration signal (that is, when bit 15 = 1 the arbiter is enabled, and when bit 15 = 0 the arbiter is disabled). See Section 2.4, “Configuration Signals Sampled at Reset,” for more information on the reset configuration signals.

If the on-chip PCI arbiter is enabled, a request-grant pair of signals is provided for each external master ($\overline{\text{REQ}}$[0:4] and $\overline{\text{GNT}}$[0:4]). In addition, there is an internal request/grant pair for the internal master state machine of the MPC8240 that governs processor accesses to PCI and PCI transactions initiated by the DMA controller (which functions as a PCI agent). If the on-chip PCI arbiter is disabled, the MPC8240 uses the $\overline{\text{GNT0}}$ signal as an output to issue its request to the external arbiter and uses the $\overline{\text{REQ0}}$ signal as an input to receive its grant from the external arbiter.

7.2.1 Internal Arbitration for PCI Bus Access

The internal state machine that arbitrates between the two on-chip DMA channels and processor accesses to the PCI bus is separate from the on-chip PCI bus arbiter that controls the arbitration between the MPC8240 and external PCI bus masters (enabled by the PCI arbiter control register at offset 0x46). This internal arbiter for MPC8240 resources is always enabled, and its output is the combined internal request/grant pair for the MPC8240. The order of progression of priorities between these accesses is shown in Figure 7-1.

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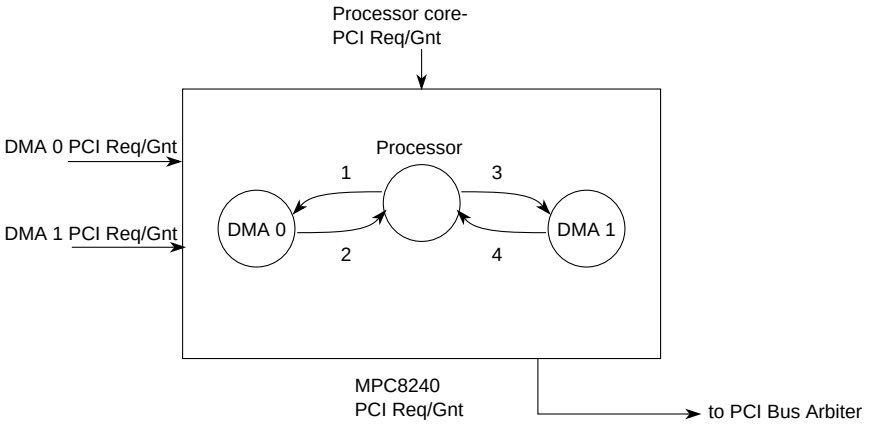

Figure 7-1. Internal Processor-DMA Arbitration for PCI Bus

As shown in Figure 7-1, the priorities propagate as follows: processor-DMA channel 0-processor-DMA channel 1-processor-DMA channel 0, and so on. Processor and DMA transactions allow for rearbitration (arbiter state transitions) at PCI transaction boundaries.

7.2.1.1 Processor-Initiated Transactions to PCI Bus

The PCI transaction boundaries for processor-initiated transactions occur at the successful completion of each processor transaction. Note that processor transactions to the PCI bus may be interrupted before completion by the loss of mastership on the PCI bus or by the PCI latency timer described in Section 4.2.6, “Latency Timer—Offset 0x0D.” However, this case does not constitute a PCI transaction boundary, and when the MPC8240 regains mastership of the external PCI bus, the processor transaction in progress continues without rearbitration with the DMA controller.

7.2.1.2 DMA-Initiated Transactions to the PCI Bus

PCI transaction boundaries for DMA-initiated transactions allow for rearbitration (arbiter state transitions) after the transmission of up to 4 Kbytes on the PCI bus. In order for a DMA channel to stream (up to 4 Kbytes) between the local memory and the PCI bus, the local memory interface (and the DMA queues) must also be available to sustain the streaming. See Section 12.2, “Internal Arbitration,” for more information on priorities for access to the local memory interface.

DMA streams (up to 4 Kbytes) from local memory to the PCI bus can cause both the local memory and PCI interface to transfer up to 4 Kbytes without interruption. Additionally, DMA transfers from PCI to local memory can cause up to 4 Kbytes to be read from the PCI bus without interruption by the MPC8240. Note, however, that DMA writes (in this case, from PCI) to local memory occur in increments of single cache lines at a time.

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Note that the latency timer parameter in the PCI latency timer register (PLTR) can affect the streaming of data to the PCI bus. If the latency timer is set to be a shorter period than the time required to transfer 4 Kbytes, then the PCI stream breaks when another PCI master is granted mastership of the PCI bus. The latency timer parameter in the PCI latency timer register (PLTR) is further described in Section 4.2.6, “Latency Timer—Offset 0x0D.”

Thus, similar to processor-initiated transactions, DMA-initiated transactions to the PCI bus may be interrupted before completion by the loss of mastership on the PCI bus or by the PCI latency timer. This case does not constitute a PCI transaction boundary, and when the MPC8240 regains mastership of the external PCI bus, the DMA stream in progress continues without rearbitration with the processor.

7.2.2 PCI Bus Arbiter Operation

The following subsections describe the operation of the on-chip PCI arbiter that arbitrates between external PCI masters and the internal PCI bus master of the MPC8240.

The on-chip PCI arbiter uses a programmable two-level, round-robin arbitration algorithm. Each of the five external masters, plus the MPC8240, can be programmed for two priority levels, high or low, using the appropriate bits in the PACR. Within each priority group (high or low), the PCI bus grant is asserted to the next requesting device in numerical order, with the MPC8240 positioned before device 0.

Conceptually, the lowest priority device is the master that is currently using the bus, and the highest priority device is the device that follows the current master in numerical order and group priority. This is considered to be a fair algorithm, since a single device cannot prevent other devices from having access to the bus; it automatically becomes the lowest priority device as soon as it begins to use the bus. If a master is not requesting the bus, then its transaction slot is given to the next requesting device within its priority group.

A grant is awarded to the highest priority requesting device as soon as the current master begins a transaction; however, the granted device must wait until the bus is relinquished by the current master before initiating a transaction.

The grant given to a particular device may be removed and awarded to another, higher priority device, whenever the higher priority device asserts its request. If the bus is idle when a device requests the bus, then for one clock cycle the arbiter withholds the grant. The arbiter re-evaluates the priorities of all requesting devices and grants the bus to the highest priority device in the following clock cycle. This allows a turnaround clock when a higher priority device is using address stepping or when the bus is parked.

The low-priority group collectively has one bus transaction request slot in the high-priority group. Mathematically, if there are N high-priority devices, and M low-priority devices, then each high-priority device is guaranteed to get at least 1 of N+1 bus transactions, and each low priority device is guaranteed to get at least 1 of (N+1) x M bus transactions, with one of the low-priority devices receiving the grant in 1 of N+1 bus transactions. If all

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devices are programmed to the same priority level, or if there is only one device in the low priority group, then the arbitration algorithm defaults to each device receiving an equal number of bus grants, in round-robin sequence.

Figure 7-2 shows an example of the arbitration algorithm. Assume that several masters are requesting use of the bus. If there are two masters in the high priority group and three in the low priority group, then each high-priority master is guaranteed at least 1 out of 3 transaction slots, and each low-priority master is guaranteed 1 out of 9 transaction slots.

In Figure 7-2, the grant sequence (with all devices except device 4 requesting the bus and device 3 being the current master) is 0, 2, MPC8240, 0, 2, 1, 0, 2, 3, … and repeating. If device 2 is not requesting the bus, then the grant sequence is 0, MPC8240, 0, 1, 0, 3, … and repeating. If device 2 requests the bus when device 0 is conducting a transaction and the MPC8240 has the next grant, then the MPC8240 will have its grant removed and device 2 will be awarded the grant since device 2 is of higher priority than the MPC8240 when device 0 has the bus.

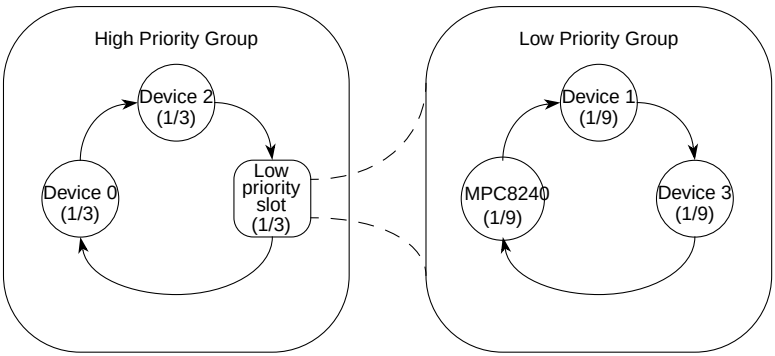

Figure 7-2. PCI Arbitration Example

7.2.3 PCI Bus Parking

When no device is using or requesting the bus, the PCI arbiter grants the bus to a selected device. This is known as parking the bus on the selected device. The selected device is required to drive the AD[31:0], $\overline{\text{C/BE}}$[0:3] and PAR signals to a stable value, preventing these signals from floating.

The parking mode control parameter (bits 14–13) in the PACR determines which device the arbiter selects for parking the PCI bus as shown in Table 7-1. If the parking mode control bits are 0b00 (or if the bus is not idle), then the bus is parked on the last master to use the bus. If the bus is idle, and the parking mode control bits are b10, then the bus is parked on the MPC8240; if the control bits are b01, then the bus is parked on device 0 (that is, the device connected to $\overline{\text{GNT0}}$).

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Table 7-1. PCI Arbiter Control Register Parking Mode Bits

PCI Arbiter Control Register [14–13]	Parking Mode
00	Parked on last master
01	Parked on the device using $\overline{\text{REQ}}$0 and $\overline{\text{GNT}}$0
10	Parked on MPC8240
11	Reserved

7.2.4 Power-Saving Modes and the PCI Arbiter

In the sleep power-saving mode, the clock signal driving PCI_SYNC_IN can be disabled. If the clock is disabled, the arbitration logic is not able to perform its function. System programmers must park the bus with a device that can sustain the AD[31:0], $\overline{\text{C/BE}}$[3:0] and PAR signals prior to disabling the PCI_SYNC_IN signal. If the bus is parked on the MPC8240 when its clocks are stopped, then the MPC8240 sustains the AD[31:0], $\overline{\text{C/BE}}$[3:0] and PAR signals in their prior states. In this situation, the only way for another agent to use the PCI bus is by waking the MPC8240. In nap and doze power-saving modes, the arbiter continues to operate allowing other PCI devices to run transactions.

7.2.5 Broken Master Lock-Out

The PCI bus arbiter on the MPC8240 has a feature that allows it to lock out any masters that are broken or ill-behaved. The broken master feature is controlled by programming bit 12 of the PCI arbitration control register (0b0 = enabled, 0b1 = disabled).

When the broken master feature is enabled, a granted device that does not assert $\overline{\text{FRAME}}$ within 16 PCI clock cycles after the bus is idle will have its grant removed and subsequent requests will be ignored until its $\overline{\text{REQ}}$ is negated for at least one clock cycle. This prevents ill-behaved masters from monopolizing the bus. When the broken master feature is disabled, a device that requests the bus and receives a grant never loses its grant until and unless it begins a transaction or negates its $\overline{\text{REQ}}$ signal. Disabling the broken master feature is not recommended.

7.3 PCI Bus Protocol

This section provides a general description of the PCI bus protocol. Specific PCI bus transactions are described in Section 7.4, “PCI Bus Transactions.” Refer to Figure 7-3, Figure 7-4, Figure 7-5, and Figure 7-6 for examples of the transfer-control mechanisms described in this section.

All signals are sampled on the rising edge of the PCI bus clock (PCI_SYNC_IN). Each signal has a setup and hold aperture with respect to the rising clock edge in which transitions are not allowed. Outside this aperture, signal values or transitions have no significance. See the *MPC8240 Hardware Specification* for specific setup and hold times.

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7.3.1 Basic Transfer Control

The basic PCI bus transfer mechanism is a burst. A burst is composed of an address phase followed by one or more data phases. Fundamentally, all PCI data transfers are controlled by three signals—$\overline{\text{FRAME}}$ (frame), $\overline{\text{IRDY}}$ (initiator ready), and $\overline{\text{TRDY}}$ (target ready). An initiator asserts $\overline{\text{FRAME}}$ to indicate the beginning of a PCI bus transaction and negates $\overline{\text{FRAME}}$ to indicate the end of a PCI bus transaction. An initiator negates $\overline{\text{IRDY}}$ to force wait cycles. A target negates $\overline{\text{TRDY}}$ to force wait cycles.

The PCI bus is considered idle when both $\overline{\text{FRAME}}$ and $\overline{\text{IRDY}}$ are negated. The first clock cycle in which $\overline{\text{FRAME}}$ is asserted indicates the beginning of the address phase. The address and bus command code are transferred in that first cycle. The next cycle begins the first of one or more data phases. Data is transferred between initiator and target in each cycle that both $\overline{\text{IRDY}}$ and $\overline{\text{TRDY}}$ are asserted. Wait cycles may be inserted in a data phase by the initiator (by negating $\overline{\text{IRDY}}$) or by the target (by negating $\overline{\text{TRDY}}$).

Once an initiator has asserted $\overline{\text{IRDY}}$, it cannot change $\overline{\text{IRDY}}$ or $\overline{\text{FRAME}}$ until the current data phase completes regardless of the state of $\overline{\text{TRDY}}$. Once a target has asserted $\overline{\text{TRDY}}$ or $\overline{\text{STOP}}$, it cannot change $\overline{\text{DEVSEL}}$, $\overline{\text{TRDY}}$, or $\overline{\text{STOP}}$ until the current data phase completes. In simpler terms, once an initiator or target has committed to the data transfer, it cannot change its mind.

When the initiator intends to complete only one more data transfer (which could be immediately after the address phase), $\overline{\text{FRAME}}$ is negated and $\overline{\text{IRDY}}$ is asserted (or kept asserted) indicating the initiator is ready. After the target indicates the final data transfer (by asserting $\overline{\text{TRDY}}$), the PCI bus may return to the idle state (both $\overline{\text{FRAME}}$ and $\overline{\text{IRDY}}$ are negated) unless a fast back-to-back transaction is in progress. In the case of a fast back-to-back transaction, an address phase immediately follows the last data phase.

7.3.2 PCI Bus Commands

A PCI bus command is encoded in the $\overline{\text{C/BE}}$[3:0] signals during the address phase of a PCI transaction. The bus command indicates to the target the type of transaction the initiator is requesting. Table 7-2 describes the PCI bus commands as implemented by the MPC8240.

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Table 7-2. PCI Bus Commands

$\overline{C/BE}$[3:0]	PCI Bus Command	MPC8240 Supports as an Initiator	MPC8240 Supports as a Target	Definition
0000	Interrupt-acknowledge	Yes	No	The interrupt-acknowledge command is a read (implicitly addressing the system interrupt controller). Only one device on the PCI bus should respond to the interrupt-acknowledge command. Other devices ignore the interrupt-acknowledge command. See Section 7.4.6.1, “Interrupt-Acknowledge Transactions,” for more information.
0001	Special cycle	Yes	No	The special-cycle command provides a mechanism to broadcast select messages to all devices on the PCI bus. See Section 7.4.6.2, “Special-Cycle Transactions,” for more information.
0010	I/O-read	Yes	No	The I/O-read command accesses agents mapped into the PCI I/O space.
0011	I/O-write	Yes	No	The I/O-write command accesses agents mapped into the PCI I/O space.
0100	Reserved[1]	No	No	—
0101	Reserved[1]	No	No	—
0110	Memory-read	Yes	Yes	The memory-read command accesses either local memory or agents mapped into PCI memory space, depending on the address. When a PCI master issues a memory-read command to local memory, the MPC8240 (the target) fetches data from the requested address to the end of the cache line (32 bytes) from local memory, even though all of the data may not be requested by (or sent to) the initiator.
0111	Memory-write	Yes	Yes	The memory-write command accesses either local memory or agents mapped into PCI memory space, depending on the address.
1000	Reserved[1]	No	No	—
1001	Reserved[1]	No	No	—
1010	Configuration-read	Yes	Yes	The configuration-read command accesses the 256-byte configuration space of a PCI agent. A specific agent is selected when its IDSEL signal is asserted during the address phase. See Section 7.4.5, “Configuration Cycles,” for more detail on PCI configuration cycles.
1011	Configuration-write	Yes	Yes	The configuration-write command accesses the 256-byte configuration space of a PCI agent. A specific agent is selected when its IDSEL signal is asserted during the address phase. See Section 7.4.5.2, “Accessing the PCI Configuration Space,” for more detail on PCI configuration accesses.

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Table 7-2. PCI Bus Commands (Continued)

C/BE[3:0]	PCI Bus Command	MPC8240 Supports as an Initiator	MPC8240 Supports as a Target	Definition
1100	Memory-read-multiple	Yes (for DMA cycles)	Yes	The memory-read-multiple command functions similarly to the memory-read command, but it also causes a prefetch of the next cache line (32 bytes). Note that for PCI reads from local memory, prefetching for all reads may be forced by setting bit 2 (PCI speculative read enable) of PICR1. See Section 12.1.3.1.2, “Speculative PCI Reads from Local Memory,” for more information.
1101	Dual-address-cycle	No	No	The dual-address-cycle command is used to transfer a 64-bit address (in two 32-bit address cycles) to 64-bit addressable devices. The MPC8240 does not respond to this command.
1110	Memory-read-line	Yes	Yes	The memory-read-line command indicates that an initiator is requesting the transfer of an entire cache line (32 bytes). This only occurs when the processor is performing a burst read. Note that PowerPC processors only perform burst reads when the appropriate cache is enabled and the transaction is not cache-inhibited.
1111	Memory-write-and-invalidate	Yes (for DMA cycles)	Yes	The memory-write-and-invalidate command indicates that an initiator is transferring an entire cache line (32 bytes); if this data is in any cacheable memory, that cache line needs to be invalidated.

[1] Reserved command encodings are reserved for future use. The MPC8240 does not respond to these commands.

7.3.3 Addressing

PCI defines three physical address spaces—PCI memory space, PCI I/O space, and PCI configuration space. Access to the PCI memory and I/O space is straightforward, although one must take into account the MPC8240 address map (map A or map B) being used. The address maps are described in Chapter 3, “Address Maps.” Access to the PCI configuration space is described in Section 7.4.5, “Configuration Cycles.”

Address decoding on the PCI bus is performed by every device for every PCI transaction. Each agent is responsible for decoding its own address. PCI supports two types of address decoding—positive decoding and subtractive decoding. For positive decoding, each device is looking for accesses in the address range that the device has been assigned. For subtractive decoding, one device on the bus is looking for accesses that no other device has claimed. See Section 7.3.4, “Device Selection,” for information about claiming transactions.

The information contained in the two low-order address bits (AD[1:0]) varies by the address space (memory, I/O, or configuration). Regardless of the encoding scheme, the two low-order address bits are always included in parity calculations.

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7.3.3.1 Memory Space Addressing

For memory accesses, PCI defines two types of burst ordering controlled by the two low-order bits of the address—linear incrementing (AD[1:0] = 0b00) and cache wrap mode (AD[1:0] = 0b10). The other two AD[1:0] possibilities (0b01 and 0b11) are reserved.

As an initiator, the MPC8240 always encodes AD[1:0] = 0b00 for PCI memory space accesses. As a target, the MPC8240 executes a target disconnect after the first data phase completes if AD[1:0] = 0b01 or AD[1:0] = 0b11 during the address phase of a local memory access. See Section 7.4.3.2, “Target-Initiated Termination,” for more information on target disconnect conditions.

Table 7-3. Supported Combinations of AD[1:0]

AD[1:0]		MPC8240 as Target		MPC8240 as Initiator	
		Read	Write	Read	Write
00	Linear	√	√	√	√
01	reserved	TD	TD	—	—
10	Cache wrap	√	TD	—	—
11	reserved	TD	TD	—	—

For linear incrementing mode, the memory address is encoded/decoded using AD[31:2]. Thereafter, the address is incremented by 4 bytes after each data phase completes until the transaction is terminated or completed (a 4-byte data width per data phase is implied). Note that the two low-order bits on the address bus are included in all parity calculations.

For cache wrap mode (AD[1:0] = 0b10) reads, the critical memory address is decoded using AD[31:2]. The address is incremented by 4 bytes after each data phase completes until the end of the cache line is reached. For cache-wrap reads, the address wraps to the beginning of the current cache line and continues incrementing until the entire cache line (32 bytes) is read. The MPC8240 does not support cache-wrap write operations and executes a target disconnect after the first data phase completes for writes with AD[1:0] = 0b10. Again, note that the two low-order bits on the address bus are included in all parity calculations.

7.3.3.2 I/O Space Addressing

For PCI I/O accesses, all 32 address signals (AD[31:0]) are used to provide a byte address. After a target has claimed an I/O access, it must determine if it can complete the entire access as indicated by the byte enable signals. If all the selected bytes are not in the address range of the target, the entire access cannot complete. In this case, the target does not transfer any data and terminates the transaction with a target-abort error. See Section 7.4.3.2, “Target-Initiated Termination,” for more information.

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7.3.3.3 Configuration Space Addressing

PCI supports two types of configuration accesses which use different formats for the AD[31:0] signals during the address phase. The two low-order bits of the address indicate the format used for the configuration address phase—type 0 (AD[1:0] = 0b00) or type 1 (AD[1:0] = 0b01). Both address formats identify a specific device and a specific configuration register for that device. See Section 7.4.5, "Configuration Cycles," for descriptions of the two formats.

7.3.4 Device Selection

The $\overline{\text{DEVSEL}}$ signal is driven by the target of the current transaction. $\overline{\text{DEVSEL}}$ indicates to the other devices on the PCI bus that the target has decoded the address and claimed the transaction. $\overline{\text{DEVSEL}}$ may be driven one, two, or three clock cycles (fast, medium, or slow device select timing) following the address phase. Device select timing is encoded into the device's PCI status register. If no agent asserts $\overline{\text{DEVSEL}}$ within three clock cycles of $\overline{\text{FRAME}}$, the agent responsible for subtractive decoding may claim the transaction by asserting $\overline{\text{DEVSEL}}$.

A target must assert $\overline{\text{DEVSEL}}$ (claim the transaction) before or coincident with any other target response (assert its $\overline{\text{TRDY}}$, $\overline{\text{STOP}}$, or data signals). In all cases except target-abort, once a target asserts $\overline{\text{DEVSEL}}$, it must not negate $\overline{\text{DEVSEL}}$ until $\overline{\text{FRAME}}$ is negated (with $\overline{\text{IRDY}}$ asserted) and the last data phase has completed. For normal termination, negation of $\overline{\text{DEVSEL}}$ coincides with the negation of $\overline{\text{TRDY}}$ or $\overline{\text{STOP}}$.

If the first access maps into a target's address range, that target asserts $\overline{\text{DEVSEL}}$ to claim the access. However, if the initiator attempts to continue the burst access across the resource boundary, then the target must issue a target disconnect.

The MPC8240 is hardwired for fast device select timing (PCI status register[10–9] = 0b00). Therefore, when the MPC8240 is the target of a transaction (local memory access or configuration register access in agent mode), it asserts $\overline{\text{DEVSEL}}$ one clock cycle following the address phase.

As an initiator, if the MPC8240 does not detect the assertion of $\overline{\text{DEVSEL}}$ within four clock cycles after the address phase (that is, five clock cycles after it asserts $\overline{\text{FRAME}}$), it terminates the transaction with a master-abort termination; see Section 7.4.3.1, "Master-Initiated Termination."

7.3.5 Byte Alignment

The byte enable signals of the PCI bus ($\overline{\text{C/BE}}$[3:0], during a data phase) are used to determine which byte lanes carry meaningful data. The byte enable signals may enable different bytes for each of the data phases. The byte enables are valid on the edge of the clock that starts each data phase and stay valid for the entire data phase. Note that parity is calculated for all bytes regardless of the state of the byte enable signals. See Section 7.6.1, "PCI Parity," for more information.

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If the MPC8240, as a target, detects no byte enables asserted, it completes the current data phase with no permanent change. This implies that on a read transaction the MPC8240 expects that the data is not changed, and on a write transaction, that ‘the data is not stored.

7.3.6 Bus Driving and Turnaround

To avoid contention, a turnaround cycle is required on all signals that may be driven by more than one agent. The turnaround cycle occurs at different times for different signals. The $\overline{\text{IRDY}}$, $\overline{\text{TRDY}}$, $\overline{\text{DEVSEL}}$, and $\overline{\text{STOP}}$ signals use the address phase as their turnaround cycle. $\overline{\text{FRAME}}$, $\overline{\text{C/BE}}$[3:0], and AD[31:0] signals use the idle cycle between transactions (when both $\overline{\text{FRAME}}$ and $\overline{\text{IRDY}}$ are negated) as their turnaround cycle. The $\overline{\text{PERR}}$ signal has a turnaround cycle on the fourth clock after the last data phase.

The PCI address/data signals, AD[31:0], are driven to a stable condition during every address/data phase. Even when the byte enables indicate that byte lanes carry meaningless data, the signals carry stable values. Parity is calculated on all bytes regardless of the byte enables. See Section 7.6.1, “PCI Parity,” for more information.

7.4 PCI Bus Transactions

This section provides descriptions of the PCI bus transactions. All bus transactions follow the protocol as described in Section 7.3, “PCI Bus Protocol.” Read and write transactions are similar for the memory and I/O spaces, so they are described as generic read transactions and generic write transactions.

The timing diagrams in this section show the relationship of significant signals involved in bus transactions. When a signal is drawn as a solid line, it is actively being driven by the current master or target. When a signal is drawn as a dashed line, no agent is actively driving it. High-impedance signals are indicated to have indeterminate values when the dashed line is between the two rails.

The terms ‘edge’ and ‘clock edge’ always refer to the rising edge of the clock. The terms ‘asserted’ and ‘negated’ always refer to the globally visible state of the signal on the clock edge, and not to signal transitions. ‘ ’ represents a turnaround cycle in the timing diagrams.

7.4.1 PCI Read Transactions

This section describes PCI single-beat read transactions and PCI burst read transactions.

A read transaction starts with the address phase, occurring when an initiator asserts $\overline{\text{FRAME}}$. During the address phase, AD[31:0] contain a valid address and $\overline{\text{C/BE}}$[3:0] contain a valid bus command.

The first data phase of a read transaction requires a turnaround cycle. This allows the transition from the initiator driving AD[31:0] as address signals to the target driving

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AD[31:0] as data signals. The turnaround cycle is enforced by the target with the $\overline{\text{TRDY}}$ signal. The target provides valid data at the earliest one cycle after the turnaround cycle. The target must drive the AD[31:0] signals when $\overline{\text{DEVSEL}}$ is asserted.

During the data phase, the $\overline{\text{C/BE}}$[3:0] signals indicate which byte lanes are involved in the current data phase. A data phase may consist of a data transfer and wait cycles. The $\overline{\text{C/BE}}$[3:0] signals remain actively driven for both reads and writes from the first clock of the data phase through the end of the transaction.

A data phase completes when data is transferred, which occurs when both $\overline{\text{IRDY}}$ and $\overline{\text{TRDY}}$ are asserted on the same clock edge. When either $\overline{\text{IRDY}}$ or $\overline{\text{TRDY}}$ is negated, a wait cycle is inserted and no data is transferred. The initiator indicates the last data phase by negating $\overline{\text{FRAME}}$ when $\overline{\text{IRDY}}$ is asserted. The transaction is considered complete when data is transferred in the last data phase.

Figure 7-3 illustrates a PCI single-beat read transaction. Figure 7-4 illustrates a PCI burst read transaction.

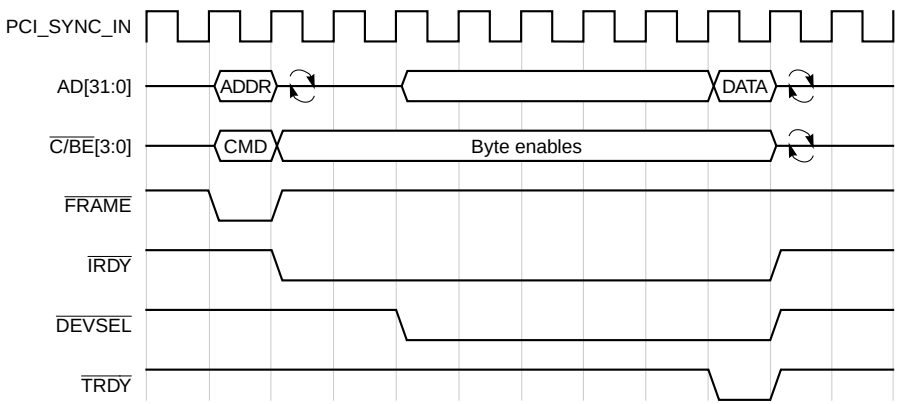

Figure 7-3. PCI Single-Beat Read Transaction

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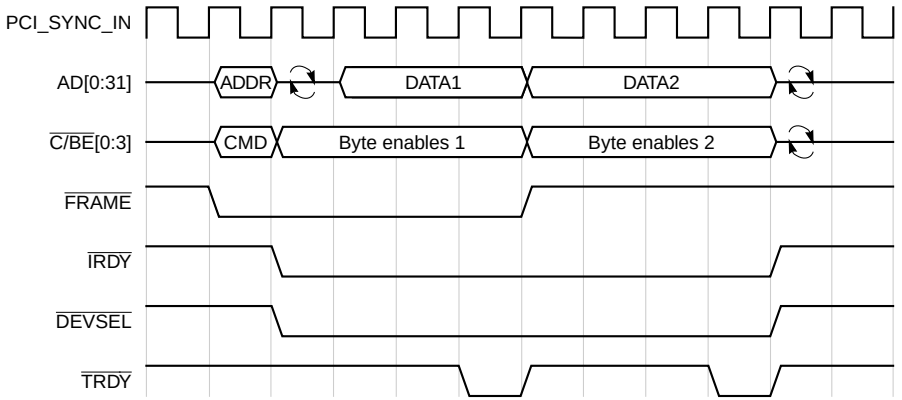

Figure 7-4. PCI Burst Read Transaction

7.4.2 PCI Write Transactions

This section describes PCI single-beat write transactions, and PCI burst write transactions. A PCI write transaction starts with the address phase, occurring when an initiator asserts FRAME. A write transaction is similar to a read transaction except no turnaround cycle is needed following the address phase because the initiator provides both address and data. The data phases are the same for both read and write transactions. Although not shown in the figures, the initiator must drive the C/BE[3:0] signals, even if the initiator is not ready to provide valid data (IRDY negated).

Figure 7-5 illustrates a PCI single-beat write transaction. Figure 7-6 illustrates a PCI burst write transaction.

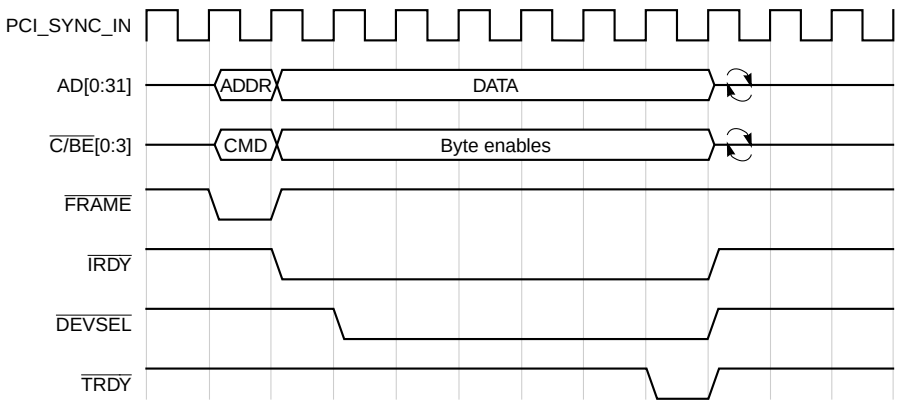

Figure 7-5. PCI Single-Beat Write Transaction

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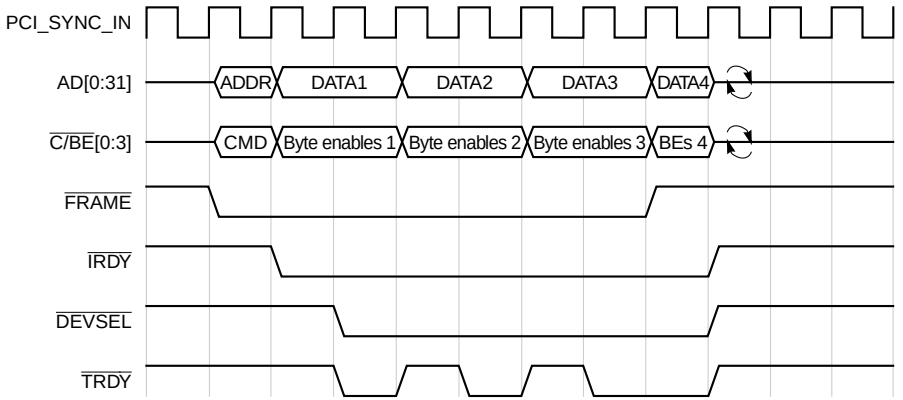

Figure 7-6. PCI Burst Write Transaction

7.4.3 Transaction Termination

A PCI transaction may be terminated by either the initiator or the target. The initiator is ultimately responsible for concluding all transactions, regardless of the cause of the termination. All transactions are concluded when $\overline{\text{FRAME}}$ and $\overline{\text{IRDY}}$ are both negated, indicating the bus is idle.

7.4.3.1 Master-Initiated Termination

Normally, a master initiates termination by negating $\overline{\text{FRAME}}$ and asserting $\overline{\text{IRDY}}$. This indicates to the target that the final data phase is in progress. The final data transfer occurs when both $\overline{\text{TRDY}}$ and $\overline{\text{IRDY}}$ are asserted. The transaction is considered complete when data is transferred in the last data phase. After the final data phase, both $\overline{\text{FRAME}}$ and $\overline{\text{IRDY}}$ are negated (the bus becomes idle).

There are three types of master-initiated termination:

- Completion—Refers to termination when the initiator has concluded its intended transaction. This is the most common reason for termination.
- Timeout—Refers to termination when the initiator loses its bus grant ($\overline{\text{GNT}}n$ is negated), and its internal latency timer has expired. The intended transaction is not necessarily concluded.
- Master-abort—An abnormal case of master-initiated termination. If no device (including the subtractive decoding agent) asserts $\overline{\text{DEVSEL}}$ to claim a transaction, the initiator terminates the transaction with a master-abort. For a master-abort termination, the initiator negates $\overline{\text{FRAME}}$ and then negates $\overline{\text{IRDY}}$ on the next clock. If a transaction is terminated by master-abort (except for a special-cycle command), the received master-abort bit (bit 13) of the PCI status register is set.

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As an initiator, if the MPC8240 does not detect the assertion of $\overline{\text{DEVSEL}}$ within four clock cycles following the address phase (five clock cycles after asserting $\overline{\text{FRAME}}$), it terminates the transaction with a master-abort. On reads that are master-aborted, the MPC8240 returns all 1s (0xFFFF). On writes that are master-aborted, the data is lost.

7.4.3.2 Target-Initiated Termination

By asserting the $\overline{\text{STOP}}$ signal, a target may request that the initiator terminate the current transaction. Once asserted, the target holds $\overline{\text{STOP}}$ asserted until the initiator negates $\overline{\text{FRAME}}$. Data may or may not be transferred during the request for termination. If $\overline{\text{TRDY}}$ and $\overline{\text{IRDY}}$ are asserted during the assertion of $\overline{\text{STOP}}$, data is transferred. However, if $\overline{\text{TRDY}}$ is negated when $\overline{\text{STOP}}$ is asserted, it indicates that the target will not transfer any more data; therefore, the initiator does not wait for a final data transfer as it would in a completion termination.

When a transaction is terminated by $\overline{\text{STOP}}$, the initiator must negate its $\overline{\text{REQ}}n$ signal for a minimum of two PCI clock cycles, (one corresponding to when the bus goes to the idle state ($\overline{\text{FRAME}}$ and $\overline{\text{IRDY}}$ negated)). If the initiator intends to complete the transaction, it can reassert its $\overline{\text{REQ}}n$ immediately following the two clock cycles. If the initiator does not intend to complete the transaction, it can assert $\overline{\text{REQ}}n$ whenever it needs to use the PCI bus again.

There are three types of target-initiated termination:

- Disconnect—Disconnect refers to termination requested because the target is temporarily unable to continue bursting. Disconnect implies that some data has been transferred. The initiator may restart the transaction at a later time starting with the address of the next untransferred data. (That is, data transfer may resume where it left off.)
- Retry—Retry refers to termination requested because the target is currently in a state where it is unable to process the transaction. Retry implies that no data was transferred. The initiator may start the entire transaction over again at a later time. Note that the *PCI Local Bus Specification*, rev 2.1 requires that all retried transactions must be completed.
- Target-abort—Target-abort is an abnormal case of target-initiated termination. Target-abort is used when a fatal error has occurred, or when a target will never be able to respond. Target-abort is indicated by asserting $\overline{\text{STOP}}$ and negating $\overline{\text{DEVSEL}}$. This indicates that the target requires termination of the transaction and does not want the transaction retried. If a transaction is terminated by target-abort, the received target-abort bit (bit 12) of the initiator's status register and the signaled target-abort bit (bit 11) of the target's status register are set. Note that any data transferred in a target-aborted transaction may be corrupt.

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As a target, the MPC8240 terminates a transaction with a target disconnect due to the following:

- It is unable to respond within eight PCI clock cycles (not including the first data phase).
- A cache line (32 bytes) of data is transferred for a cache-wrap mode read transaction. (See the discussion of cache wrap mode in Section 7.3.3.1, “Memory Space Addressing,” for more information.)
- A single beat of data is transferred for a cache-wrap mode write transaction. (See the discussion of cache wrap mode in Section 7.3.3.1, “Memory Space Addressing,” for more information.)
- The last four bytes of a cache line are transferred in linear-incrementing address mode. (See the description of linear-incrementing mode in Section 7.3.3.1, “Memory Space Addressing,” for more information.)
- If AD[1:0] = 0b01 or AD[1:0] = 0b11 during the address phase of a local memory access. (See Section 7.3.3.1, “Memory Space Addressing,” for more information.)

As a target, the MPC8240 responds to a transaction with a retry due to the following:

- A processor copyback operation is in progress.
- A PCI write to local memory was attempted when the internal PCI-to-local-memory-write buffers (PCMWBs) are full.
- A nonexclusive access was attempted to local memory while the MPC8240 was locked.
- A configuration write to a PCI device is underway and PICR2[NO_SERIAL_CFG] = 0.
- An access to one of the MPC8240 internal configuration registers is in progress.
- The 16-clock latency timer has expired, and the first data phase has not begun.

As a target, the MPC8240 responds with a target-abort if a PCI master attempts to write to the ROM/Flash ROM space in address map B. For PCI writes to local memory, if an address parity error or data parity error occurs, the MPC8240 aborts the transaction internally but continues the transaction on the PCI bus.

Figure 7-7 shows several target-initiated terminations. The three disconnect terminations are unique in the data transferred at the end of the transaction. For Disconnect A, the initiator is negating $\overline{\text{IRDY}}$ when the target asserts $\overline{\text{STOP}}$ and data is transferred only at the end of the current data phase. For Disconnect B, the target negates $\overline{\text{TRDY}}$ one clock after it asserts $\overline{\text{STOP}}$, indicating that the target can accept the current data, but no more data can be transferred. For the Disconnect-without-data, the target asserts $\overline{\text{STOP}}$ when $\overline{\text{TRDY}}$ is negated indicating that the target cannot accept any more data.

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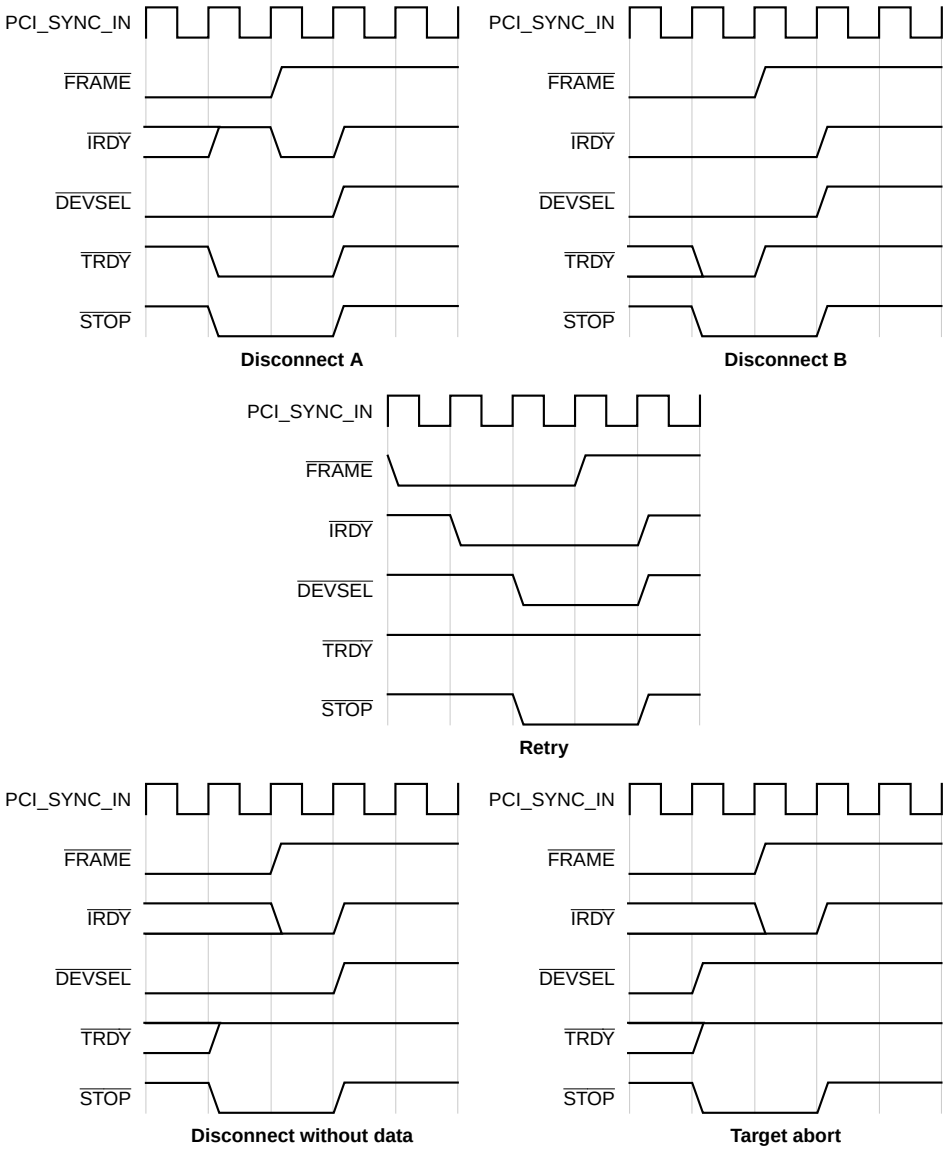

Figure 7-7. PCI Target-Initiated Terminations

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7.4.4 Fast Back-to-Back Transactions

The PCI bus allows fast back-to-back transactions by the same master. During a fast back-to-back transaction, the initiator starts the next transaction immediately without an idle state. The last data phase completes when $\overline{\text{FRAME}}$ is negated, and $\overline{\text{IRDY}}$ and $\overline{\text{TRDY}}$ are asserted. The current master starts another transaction in the clock cycle immediately following the last data transfer for the previous transaction.

Fast back-to-back transactions must avoid contention on the $\overline{\text{TRDY}}$, $\overline{\text{DEVSEL}}$, $\overline{\text{PERR}}$, and $\overline{\text{STOP}}$ signals. There are two types of fast back-to-back transactions—those that access the same target, and those that access multiple targets sequentially. The first type places the burden of avoiding contention on the initiator; the second type places the burden of avoiding contention on all potential targets.

As an initiator, the MPC8240 does not perform any fast back-to-back transactions. As a target, the MPC8240 supports both types of fast back-to-back transactions.

During fast back-to-back transactions, the MPC8240 monitors the bus states to determine if it is the target of a transaction. If the previous transaction was not directed to the MPC8240 and the current transaction is directed at the MPC8240, the MPC8240 delays the assertion of $\overline{\text{DEVSEL}}$ (as well as $\overline{\text{TRDY}}$, $\overline{\text{STOP}}$, and $\overline{\text{PERR}}$) for one clock cycle to allow the other target to stop driving the bus.

7.4.5 Configuration Cycles

This section describes PCI configuration cycles used for configuring standard PCI devices. The PCI configuration space of any device is intended for configuration, initialization, and catastrophic error-handling functions only. Access to the PCI configuration space should be limited to initialization and error-handling software.

7.4.5.1 The PCI Configuration Space Header

The first 64 bytes of the 256-byte configuration space consists of a predefined header that every PCI device must support. The predefined header is shown in Figure 7-8. The rest of the 256-byte configuration space is device-specific.

The first 16 bytes of the predefined header are defined the same for all PCI devices; the remaining 48 bytes of the header may have differing layouts depending on the function of the device. Most PCI devices use the configuration header layout shown in Figure 7-8.

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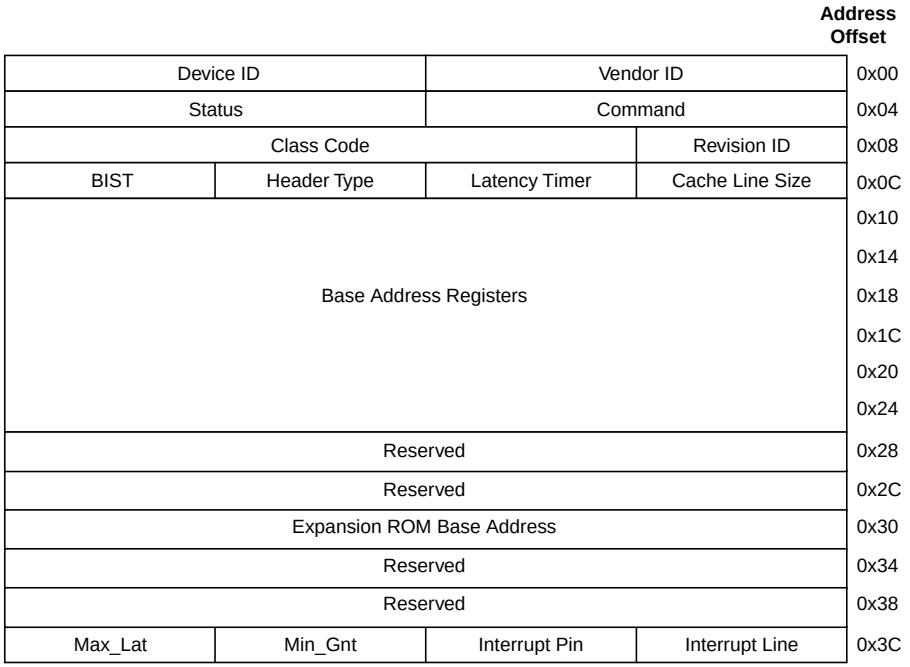

Figure 7-8. Standard PCI Configuration Header

Table 7-4 summarizes the registers of the configuration header. Detailed descriptions of these registers are provided in the *PCI Local Bus Specification*, rev 2.1.

Table 7-4. PCI Configuration Space Header Summary

Address Offset (Hex)	Register Name	Description
0x00	Vendor ID	Identifies the manufacturer of the device (assigned by the PCI SIG (special-interest group) to ensure uniqueness)
0x02	Device ID	Identifies the particular device (assigned by the vendor)
0x04	Command	Provides coarse control over a device's ability to generate and respond to PCI bus cycles
0x06	Status	Records status information for PCI bus-related events
0x08	Revision ID	Specifies a device-specific revision code (assigned by vendor)
0x09	Class code	Identifies the generic function of the device and (in some cases) a specific register-level programming interface
0x0C	Cache line size	Specifies the system cache line size in 32-bit units
0x0D	Latency timer	Specifies the value of the latency timer in PCI bus clock units for the device when acting as an initiator

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Table 7-4. PCI Configuration Space Header Summary (Continued)

Address Offset (Hex)	Register Name	Description
0x0E	Header type	Bits 0–6 identify the layout of bytes 10–3F; bit 7 indicates a multifunction device. The most common header type (0x00) is shown in Figure 7-8 and in this table.
0x0F	BIST	Optional register for control and status of built-in self test (BIST)
0x10–0x27	Base address registers	Address mapping information for memory and I/O space
0x28	—	Reserved for future use
0x2C	—	Reserved for future use
0x30	Expansion ROM base address	Base address and size information for expansion ROM contained in an add-on board
0x34	—	Reserved for future use
0x38	—	Reserved for future use
0x3C	Interrupt line	Contains interrupt line routing information
0x3D	Interrupt pin	Indicates which interrupt pin the device (or function) uses
0x3E	Min_Gnt	Specifies the length of the device's burst period in 0.25 µs units
0x3F	Max_Lat	Specifies how often the device needs to gain access to the bus in 0.25 µs units

7.4.5.2 Accessing the PCI Configuration Space

This section describes accessing the external PCI configuration space. See Section 7.7.2, "Accessing the MPC8240 Configuration Space," for information on accessing the internal configuration registers of the MPC8240.

To support hierarchical bridges, two types of configuration accesses are supported. The first type of configuration access, type 0, is used to select a device on the local PCI bus. Type 0 configuration accesses are not propagated beyond the local PCI bus and must be claimed by a local device or terminated with a master-abort. The second type of configuration access, type 1, is used to pass a configuration request to another PCI bus (through a PCI-to-PCI bridge). Type 1 accesses are ignored by all targets except PCI-to-PCI bridges.

To access the configuration space, a 32-bit value must be written to the CONFIG_ADDR register that specifies the target PCI bus, the target device on that bus, and the configuration register to be accessed within that device. A read or write to the CONFIG_DATA register causes the host bridge to translate the access into a PCI configuration cycle (provided the enable bit in CONFIG_ADDR is set and the device number is not 0b1_1111).

For the MPC8240, the CONFIG_ADDR register is located at different addresses depending on the memory address map in use. The address maps are described in Chapter 3, "Address Maps." For address map B, the processor can access the CONFIG_ADDR register at any location in the address range from 0xFEC0_0000 to 0xFEDF_FFFF. For simplicity, the address for CONFIG_ADDR is sometimes referred to as CF8, 0xnnnn_nCF8, or (in the PCI literature as) CF8h. Although systems implementing address map B can use any

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address in the range from 0xFEC0_0000 to 0xFEDF_FFFF for the CONFIG_ADDR register, the address 0xFEC0_0CF8 may be the most intuitive location. For address map A, the processor core can access the CONFIG_ADDR register through the MPC8240 at 0x8000_0CF8. See Appendix A for more information on address map A.

The format of CONFIG_ADDR is shown in Figure 7-9.

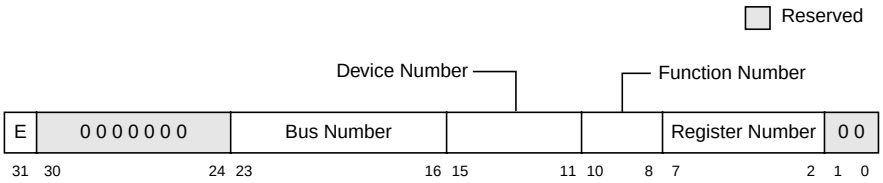

Figure 7-9. CONFIG_ADDR Register Format

Table 7-5 describes the fields within CONFIG_ADDR.

Table 7-5. CONFIG_ADDR Register Fields

Bits	Field Name	Description
31	E(nable)	The enable flag controls whether accesses to CONFIG_DATA are translated into PCI configuration cycles. 1 Enabled 0 Disabled
30–24	—	Reserved (must be 0b000_0000)
23–16	Bus number	This field is an encoded value used to select the target bus of the configuration access. For target devices on the PCI bus connected to the MPC8240, this field should be set to 0x00.
15–11	Device number	This field is used to select a specific device on the target bus.
10–8	Function number	This field is used to select a specific function in the requested device. Single-function devices should respond to function number 0b000.
7–2	Register number	This field is used to select the address offset in the configuration space of the target device.
1–0	—	Reserved (must be 0b00)

As with the CONFIG_ADDR register, the CONFIG_DATA register is located at different addresses depending on the memory address map in use. For address map A, the processor can access the CONFIG_DATA register through the MPC8240 at 0x8000_0CFC to 0x8000_0CFF. For address map B, the processor can access the CONFIG_DATA register at any location in the address range from 0xFEE0_0000 to 0xFEEF_FFFF. For simplicity, the address for CONFIG_DATA is sometimes referred to as CFC, 0xnnnn_nCFC or CFCh (in the PCI literature as). Although systems implementing address map B can use any address in the range from 0xFEE0_0000 to 0xFEEF_FFFF for the CONFIG_DATA register, the address 0xFEE0_0CFC–0xFEE0_0CFF may be the most intuitive location.

Note that the CONFIG_DATA register may contain 1, 2, 3, or 4 bytes depending on the size of the register being accessed.

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When the MPC8240 detects an access to the CONFIG_DATA register, it checks the enable flag and the device number in the CONFIG_ADDR register. If the enable bit is set, and the device number is not 0b1_1111, the MPC8240 performs a configuration cycle translation function and runs a configuration-read or configuration-write transaction on the PCI bus. The device number 0b1_1111 is used for performing interrupt-acknowledge and special-cycle transactions. See Section 7.4.6, “Other Bus Transactions,” for more information. If the bus number corresponds to the local PCI bus (bus number = 0x00), the MPC8240 performs a type 0 configuration cycle translation. If the bus number indicates a remote PCI bus (that is, nonlocal), the MPC8240 performs a type 1 configuration cycle translation.

7.4.5.2.1 Type 0 Configuration Translation

Figure 7-10 shows the type 0 translation function performed on the contents of the CONFIG_ADDR register to the AD[31:0] signals on the PCI bus during the address phase of the configuration cycle.

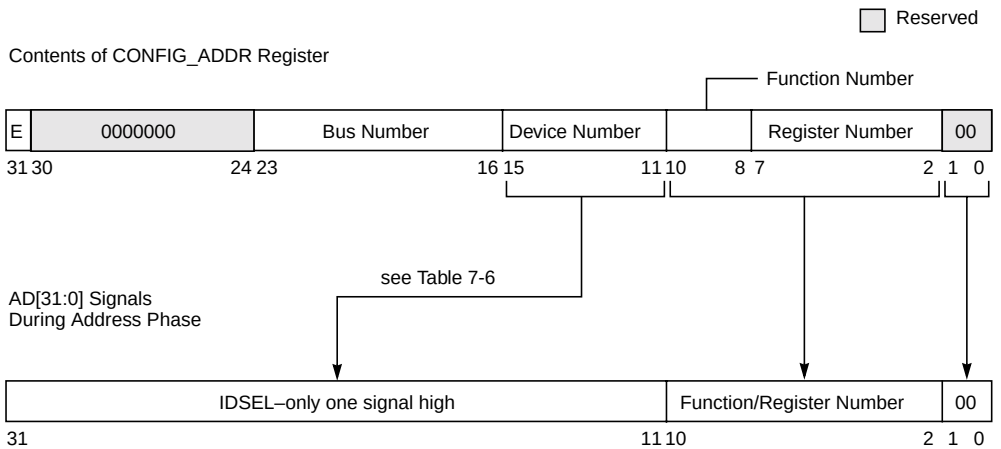

Figure 7-10. Type 0 Configuration Translation

For type 0 configuration cycles, the MPC8240 translates the device number field of the CONFIG_ADDR register into a unique IDSEL signal for up to 21 different devices. Each device connects its IDSEL input to one of the AD[31:11] signals. For type 0 configuration cycles, the MPC8240 translates the device number to IDSEL as shown in Table 7-6.

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Table 7-6. Type 0 Configuration—Device Number to IDSEL Translation

Device Number		IDSEL
Binary	Decimal	
0b0_0000–0b0_1001	0–9	—
0b0_1010	10	AD31
0b0_1011	11	AD11
0b0_1100	12	AD12
0b0_1101	13	AD13
0b0_1110	14	AD14
0b0_1111	15	AD15
0b1_0000	16	AD16
0b1_0001	17	AD17
0b1_0010	18	AD18
0b1_0011	19	AD19
0b1_0100	20	AD20
0b1_0101	21	AD21
0b1_0110	22	AD22
0b1_0111	23	AD23
0b1_1000	24	AD24
0b1_1001	25	AD25
0b1_1010	26	AD26
0b1_1011	27	AD27
0b1_1100	28	AD28
0b1_1101	29	AD29
0b1_1110	30	AD30
0b1_1111[1]	31	—

[1] A device number of all 1s indicates a PCI special-cycle or interrupt-acknowledge transaction.

Note that the MPC8240 must not issue PCI configuration transactions to itself (that is, for PCI configuration transactions initiated by the MPC8240, its IDSEL input signal must not be asserted).

For type 0 translations, the function number and register number fields are copied without modification onto the AD[10:2] signals during the address phase. The AD[1:0] signals are driven to 0b00 during the address phase for type 0 configuration cycles.

For systems implementing address map A on the MPC8240, there is an alternate method for generating type 0 configuration cycles, called the direct access method. See Section A.2, “Configuration Accesses Using Direct Method,” for more information.

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7.4.5.2.2 Type 1 Configuration Translation

For type 1 translations, the MPC8240 copies the 30 high-order bits of the CONFIG_ADDR register (without modification) onto the AD[31:2] signals during the address phase. The MPC8240 automatically translates AD[1:0] into 0b01 during the address phase to indicate a type 1 configuration cycle.

7.4.6 Other Bus Transactions

There are two other PCI transactions that the MPC8240 supports—interrupt-acknowledge and special cycles. As an initiator, the MPC8240 may initiate both interrupt-acknowledge and special-cycle transactions; however, as a target, the MPC8240 ignores interrupt-acknowledge and special-cycle transactions. Both transactions make use of the CONFIG_ADDR and CONFIG_DATA registers described in Section 7.4.5.2, "Accessing the PCI Configuration Space."

7.4.6.1 Interrupt-Acknowledge Transactions

The PCI bus supports an interrupt-acknowledge transaction. The interrupt-acknowledge command is a read operation implicitly addressed to the system interrupt controller. Note that the PCI interrupt-acknowledge command does not address the MPC8240's EPIC processor interrupt-acknowledge register and does not return the interrupt vector address from the EPIC unit. See Chapter 11, "Embedded Programmable Interrupt Controller (EPIC) Unit," for more information about the EPIC unit.

When the MPC8240 detects a read to the CONFIG_DATA register, it checks the enable flag and the device number in the CONFIG_ADDR register. If the enable bit is set, the bus number corresponds to the local PCI bus (bus number = 0x00), the device number is all 1s (0b1_1111), the function number is all 1s (0b111), and the register number is zero (0b00_0000), then the MPC8240 performs an interrupt-acknowledge transaction. If the bus number indicates a nonlocal PCI bus, the MPC8240 performs a type 1 configuration cycle translation, similar to any other configuration cycle for which the bus number does not match.

The address phase contains no valid information other than the interrupt-acknowledge command ($\overline{C/BE}$[3:0] = 0b0000). Although there is no explicit address, AD[31:0] are driven to a stable state, and parity is generated. Only one device (the system interrupt controller) on the PCI bus should respond to the interrupt-acknowledge command by asserting $\overline{DEVSEL}$. All other devices on the bus should ignore the interrupt-acknowledge command. As stated previously, the MPC8240's EPIC unit does not respond to PCI interrupt-acknowledge commands.

During the data phase, the responding device returns the interrupt vector on AD[31:0] when $\overline{TRDY}$ is asserted. The size of the interrupt vector returned is indicated by the value driven on the $\overline{C/BE}$[3:0] signals.

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The MPC8240 also provides a direct method for generating PCI interrupt-acknowledge transactions. For address map A, processor reads to 0xBFFF_FFF0–0xBFFF_FFFF generate PCI interrupt-acknowledge transactions. For address map B, processor reads to any location in the address range 0xFEF0_0000–0xFEFF_FFFF generate PCI interrupt-acknowledge transactions. Note that processor writes to these addresses cause processor transaction errors; see Section 13.3.1.1, “Processor Transaction Error,” for more information.

7.4.6.2 Special-Cycle Transactions

The special-cycle command provides a mechanism to broadcast select messages to all devices on the PCI bus. The special-cycle command contains no explicit destination address but is broadcast to all PCI agents.

When the MPC8240 detects a write to the CONFIG_DATA register, it checks the enable flag and the device number in the CONFIG_ADDR register. If the enable bit is set, the bus number corresponds to the local PCI bus (bus number = 0x00), the device number is all 1s (0b1_1111), the function number is all 1s (0b111), and the register number is zero (0b00_0000), then the MPC8240 performs a special-cycle transaction on the local PCI bus. If the bus number indicates a nonlocal PCI bus, the MPC8240 performs a type 1 configuration cycle translation, similar to any other configuration cycle for which the bus number does not match.

Aside from the special-cycle command ($\overline{\text{C/BE}}$[3:0] = 0b0001) the address phase contains no other valid information. Although there is no explicit address, AD[31:0] are driven to a stable state, and parity is generated. During the data phase, AD[31:0] contain the special-cycle message and an optional data field. The special-cycle message is encoded on the 16 least-significant bits (AD[15:0]); the optional data field is encoded on the most-significant 16 lines (AD[31:16]). The special-cycle message encodings are assigned by the PCI SIG steering committee. The current list of defined encodings are provided in Table 7-7.

Table 7-7. Special-Cycle Message Encodings

AD[15:0]	Message
0x0000	SHUTDOWN
0x0001	HALT
0x0002	x86 architecture-specific
0x0003–0xFFFF	—

Note that the MPC8240 does not automatically issue a special-cycle message when it enters any of its power-saving modes. It is the responsibility of software to issue the appropriate special-cycle message, if needed.

Each receiving agent must determine whether the special-cycle message is applicable to itself. Assertion of $\overline{\text{DEVSEL}}$ in response to a special-cycle command is not necessary. The

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initiator of the special-cycle transaction can insert wait states but since there is no specific target, the special-cycle message and optional data field are valid on the first clock $\overline{\text{IRDY}}$ is asserted. All special-cycle transactions are terminated by master-abort; however, the master-abort bit in the initiator's status register is not set for special-cycle terminations.

7.5 Exclusive Access

PCI provides an exclusive access mechanism referred to as a resource lock. The mechanism locks only the selected PCI resource (typically memory) but allows other nonexclusive accesses to unlocked targets. In this section, the term 'locked operation' means an exclusive access to a locked target that may span several PCI transactions. A full description of exclusive access is contained in the *PCI Local Bus Specification*, rev 2.1.

The $\overline{\text{LOCK}}$ signal indicates that an exclusive access is underway. The assertion of $\overline{\text{GNT}}$ does not guarantee control of the $\overline{\text{LOCK}}$ signal. Control of $\overline{\text{LOCK}}$ is obtained in conjunction with $\overline{\text{GNT}}$. When using the resource lock, agents performing nonexclusive accesses are free to proceed even while another master retains ownership of $\overline{\text{LOCK}}$.

7.5.1 Starting an Exclusive Access

To initiate a locked operation, an initiator must receive $\overline{\text{GNT}}$ when the $\overline{\text{LOCK}}$ signal is not busy. The initiator is then said to own the $\overline{\text{LOCK}}$ signal. To request a resource lock, the initiator must hold $\overline{\text{LOCK}}$ negated during the address phase of a read command and assert $\overline{\text{LOCK}}$ in the clock cycle following the address phase. Note that the first transaction of a locked operation must be a read transaction.

The locked operation is not established on the PCI bus until the first data transfer ($\overline{\text{IRDY}}$ and $\overline{\text{TRDY}}$ asserted) completes. Once the lock is established, the initiator may retain ownership of the $\overline{\text{LOCK}}$ signal and the target may remain locked beyond the end of the current transaction. The initiator holds $\overline{\text{LOCK}}$ asserted until either the locked operation completes or until an error (master-abort or target-abort) causes an early termination. A target remains in the locked state until both $\overline{\text{FRAME}}$ and $\overline{\text{LOCK}}$ are negated. If the target retries the first transaction without a data phase completing, the initiator should not only terminate the transaction but also negate $\overline{\text{LOCK}}$.

7.5.2 Continuing an Exclusive Access

When the lock owner is granted access to the bus for another exclusive access to the previously-locked target, it negates the $\overline{\text{LOCK}}$ signal during the address phase to reestablish the lock. The locked target accepts the transaction and claims the transaction. The initiator then asserts $\overline{\text{LOCK}}$ in the clock cycle following the address phase. If the initiator plans to continue the locked operation, it continues to assert $\overline{\text{LOCK}}$.

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7.5.3 Completing an Exclusive Access

When an initiator is ready to complete an exclusive access, it should negate $\overline{\text{LOCK}}$ when $\overline{\text{IRDY}}$ is negated following the completion of the last data phase of the locked operation. This is to ensure that the target is released prior to any other operation and the resource is no longer blocked.

7.5.4 Attempting to Access a Locked Target

If $\overline{\text{LOCK}}$ is asserted during the address phase to a locked target, the locked target signals a retry, terminating the transaction without transferring any data. (The lock master always negates $\overline{\text{LOCK}}$ during the address phase of a transaction to a locked target.) Nonlocked targets ignore the $\overline{\text{LOCK}}$ signal when decoding the address. This allows other PCI agents to initiate and respond to transactions while maintaining exclusive access to the locked target.

7.5.5 Exclusive Access and the MPC8240

As an initiator, the MPC8240 does not generate locked operations. As a target, the MPC8240 responds to locked operations by guaranteeing complete access exclusion to local memory from the point-of-view of the PCI bus. From the point of view of the processor core, only the cache line (32 bytes) of the transaction is locked.

If an initiator on the PCI bus asserts $\overline{\text{LOCK}}$ for a read transaction to local memory, the MPC8240 completes the snoop transactions for any previous PCI-to-local-memory write operations and performs a snoop transaction for the locked read operation on the internal peripheral logic bus. Subsequent processor core accesses to local memory, when $\overline{\text{LOCK}}$ is asserted, are permitted with the exception that if the processor core attempts to access addresses within the locked cache line, the MPC8240 will retry the processor until the locked operation is completed. If a locked operation covers more than one cache line (32 bytes), only the most recently accessed cache line is locked from the processor. Since a snoop transaction is required to establish a lock, the MPC8240 does not honor the assertion of $\overline{\text{LOCK}}$ when PICR1[NO_SNOOP_EN] is set.

7.6 PCI Error Functions

PCI provides for parity and other system errors to be detected and reported. This section describes generation and detection of parity and error reporting for the PCI bus.

The PCI command register and error enabling registers 1 and 2 provide for selective enabling of specific PCI error detection. The PCI status register, error detection registers 1 and 2, the PCI bus error status register, and the 60x/PCI error address register provide PCI error reporting. These registers are described in Chapter 4, “Configuration Registers.”

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7.6.1 PCI Parity

Generating parity is not optional; it must be performed by all PCI-compliant devices. All PCI transactions, regardless of type, calculate even parity; that is, the number of 1s on the AD[31:0], $\overline{C/BE}$[3:0], and PAR signals all sum to an even number.

Parity provides a way to determine, on each transaction, if the initiator successfully addressed the target and transferred valid data. The $\overline{C/BE}$[3:0] signals are included in the parity calculation to ensure that the correct bus command is performed (during the address phase) and correct data is transferred (during the data phase). The agent responsible for driving the bus must also drive even parity on the PAR signal one clock cycle after a valid address phase or valid data transfer, as shown in Figure 7-11.

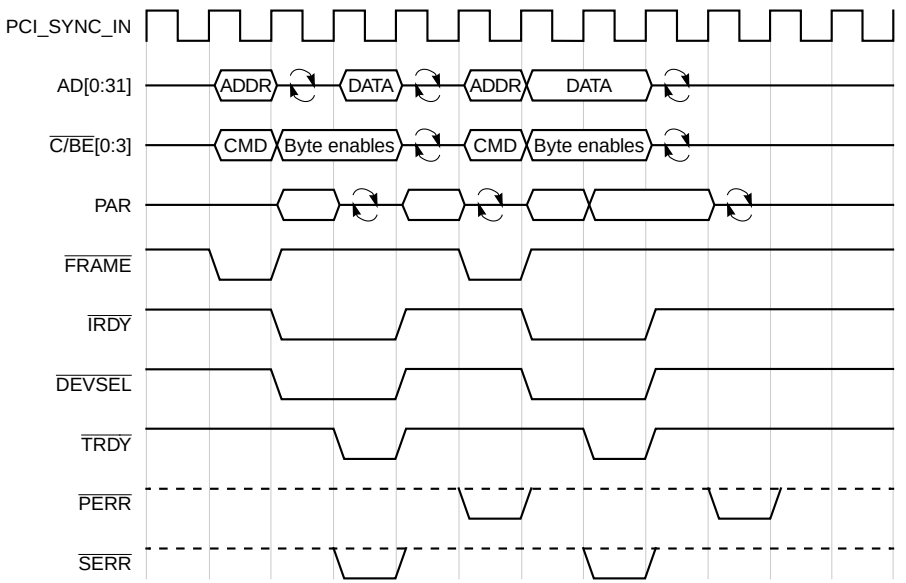

Figure 7-11. PCI Parity Operation

During the address and data phases, parity covers all 32 address/data signals and the four command/byte enable signals regardless of whether all lines carry meaningful information. Byte lanes not actually transferring data must contain stable (albeit meaningless) data and are included in parity calculation. During configuration, special-cycle, or interrupt-acknowledge commands, some address lines are not defined but are driven to stable values and are included in parity calculation.

Agents that support parity checking must set the detected parity error bit in the PCI status register when a parity error is detected. Any additional response to a parity error is controlled by the parity error response bit in the PCI command register. If the parity error response bit is cleared, the agent ignores all parity errors.

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7.6.2 Error Reporting

PCI provides for the detection and signaling of both parity and other system errors. Two signals are used to report these errors—$\overline{\text{PERR}}$ and $\overline{\text{SERR}}$. The $\overline{\text{PERR}}$ signal is used exclusively to report data parity errors on all transactions except special cycles. The $\overline{\text{SERR}}$ signal is used for other error signaling including address parity errors and data parity errors on special-cycle transactions; it may also be used to signal other system errors. Refer to Section 13.3.3, “PCI Interface Errors,” for a complete description of MPC8240 actions due to parity and other errors.

7.7 PCI Host and Agent Modes

This section describes the different modes available in the MPC8240.

The MPC8240 can function as either a PCI host bridge (referred to as ‘host mode’) or a peripheral device on the PCI bus (referred to as ‘agent mode’). The MAA1 configuration signal, sampled at reset, configures the MPC8240 for host or agent mode as described in Section 2.4, “Configuration Signals Sampled at Reset.” Note that agent mode is supported only for address map B. It is a configuration error to set the MPC8240 to use address map A and agent mode. Also note that in agent mode, the MPC8240 ignores all PCI memory accesses (except to the EUMB) until inbound address translation is enabled. See Section 7.7.4.1, “Inbound PCI Address Translation,” and Section 3.3.1, “Inbound PCI Address Translation,” for more information about inbound address translation.

7.7.1 PCI Initialization Options

The assertion of the $\overline{\text{HRST\_CPU}}$ and $\overline{\text{HRST\_CTRL}}$ signals (must be asserted together) cause the processor to take a hard reset exception. The physical address of the handler is always 0xFFF0_0100. Host and agent modes provide different options for initial reset exception vector fetching, and register configuration.

When the MPC8240 is configured for host mode, the system may initialize by fetching initial instructions from a ROM/Flash device. The setting of the $\overline{\text{RCS0}}$ configuration signal at the negation of the reset signals determines whether ROM/Flash is located in local memory space or in PCI memory space. See Section 2.4, “Configuration Signals Sampled at Reset,” for more information.

When the MPC8240 is configured for agent mode, it can also be configured to initialize from local memory space or remote PCI memory space.

Table 7-8 summarizes the initialization modes of the MPC8240. The initial settings of the PCI command register bus master and memory space bits (bits 2 and 1, respectively) are determined based on the reset configuration signals as shown in the table.

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Table 7-8. Initialization Options for PCI Controller

Bus Master Mode (MAA1 at Reset)	ROM Location ($\overline{\text{RCS0}}$ at Reset)	Initial Settings of PCI Command Register, and Boot Vector Fetch
Host (**MAA1** high)	Local memory space ($\overline{\text{RCS0}}$ high)	PCI command register [2,1] set to 10 Master enabled, target disabled Boot vector fetch is sent to ROM located on the local memory interface.
Host (**MAA1** high)	PCI memory space ($\overline{\text{RCS0}}$ low)	PCI command register [2,1] set to 10 Master enabled, target disabled Boot vector fetch is sent to PCI, and is issued on the bus unaltered.
Agent (**MAA1** low)	Local memory space ($\overline{\text{RCS0}}$ high)	PCI command register [2,1] set to 00 Master disabled, target disabled Boot vector fetch is sent to ROM located on the local memory bus.Processor core configures local memory and has the option to set bit 10 (RTY_PCI_CFG) of the PCI arbiter control register (PACR) to force PCI configuration cycles to be retried until local configuration is complete (see Section 7.7.3, “PCI Configuration Cycle Retry Capability in Agent Mode”). The MPC8240 can not issue transactions on the PCI bus until the master enable bit is set.
Agent (**MAA1** low)	PCI memory space ($\overline{\text{RCS0}}$ low)	PCI command register [2,1] set to 00 Master disabled, target disabled Boot vector fetch is sent to PCI bus where it is not allowed to proceed until the host CPU enables bus mastership for the MPC8240 in the PCI control register. The processor core then proceeds sending the boot vector fetch to the PCI bus unaltered.

7.7.2 Accessing the MPC8240 Configuration Space

The MPC8240 responds to PCI configuration accesses from external PCI agents when the MPC8240’s IDSEL input signal is asserted. This allows an external agent access to a subset of the MPC8240’s internal configuration registers. The configuration of the internal registers of the MPC8240 that are not accessible to external agents is described in Section 4.1, “Configuration Register Access.”

When accessing the MPC8240’s configuration registers, the external agent performs the translation shown in Figure 7-10. The external agent uses the appropriate device number to assert the MPC8240’s IDSEL input; the desired function/register number from 0x00 to 0x47 as described in Section 4.1.3.2, “PCI-Accessible Configuration Registers.”

Note that the MPC8240 must not issue PCI configuration transactions to itself (that is, for PCI configuration transactions initiated by the MPC8240, its IDSEL input signal must not be asserted).

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7.7.3 PCI Configuration Cycle Retry Capability in Agent Mode

When the MPC8240 is configured for agent mode and is initializing from ROM located on the local memory bus, it may be necessary to defer a remote host from completing PCI configuration cycles until the local device can be tested and configured.

When the MPC8240 RTY_PCI_CFG bit (bit 10 in PACR) is set, the MPC8240's PCI bus interface retries PCI configuration cycles. This mechanism allows the processor core to complete configuration of the local memory controller in advance of a system host controller. Once the MPC8240 has completed local configuration, it can clear the RTY_PCI_CFG bit, enabling the system host controller to complete configuration.

7.7.4 PCI Address Translation Support

The MPC8240 allows remapping PCI memory space transactions to local memory and processor core transactions to PCI memory space. Note that address translation is supported only for agent mode; it is not supported when the MPC8240 is operating in host mode. Also note that since agent mode is supported only for address map B, address translation is supported only for address map B. The following sections summarize the address translation support of the MPC8240. See Section 3.3, "Address Translation," for more information about the MPC8240 address translation facility.

7.7.4.1 Inbound PCI Address Translation

Inbound transactions are PCI memory space accesses initiated by an external PCI master that are targeted toward the MPC8240. Using inbound address translation, the MPC8240 claims the PCI memory space transaction and translates it to a local memory access. When the MPC8240 is in agent mode, inbound address translation allows an external PCI master to access local memory through a window in the PCI memory space.

Note that in agent mode, the MPC8240 ignores all PCI accesses to local memory until inbound address translation is enabled. That is, in agent mode, the MPC8240 responds only to the PCI configuration and to the embedded utilities memory block (EUMB) accesses until inbound translation is enabled. See Section 3.3.1, "Inbound PCI Address Translation," for a complete description of inbound PCI address translation.

7.7.4.2 Outbound PCI Address Translation

Outbound transactions are accesses initiated by the processor core that are targeted to PCI memory space. Using outbound address translation, the processor transaction is translated to an address in PCI memory space. When the MPC8240 is in agent mode, outbound address translation allows the MPC8240 to access (external) host memory in the lower 2 Gbytes of PCI memory space. See Section 3.3.2, "Outbound PCI Address Translation," for a complete description of outbound PCI address translation.

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7.7.4.3 Initialization Code Translation in Agent Mode

Since the processor always vectors to 0xFFF0_0100 after a hard reset, it may be desirable in some systems to fetch from an alternate or translated address space. This allows a system designer to place the initialization code at some alternate system memory location such as system main memory or alternate system ROM space. When configured for agent mode, outbound PCI address translation is used to accomplish this task.

The MPC8240 has the flexibility of being programmable from a remote host controller. In this case, the outbound translation window is set to map the local ROM space to an alternate system address. The following procedure must be followed to take advantage of this functionality:

1. MPC8240 is configured for agent mode, with ROM located in PCI memory space.
2. System performs a hard reset.
3. The MPC8240 processor core fetches the hard reset exception vector, which is directed to the PCI bus. The transaction stalls and can not proceed until the PCI command register master enable bit is enabled.
4. The system host controller initializes and configures the MPC8240 as an agent.
5. The host must program PCSRBAR to locate the EUMB within PCI memory space.
6. The host must set bit 1 of the PCI command register to enable MPC8240 response to PCI memory accesses.
7. The host programs the outbound translation window to contain the ROM space and the outbound translation base address to point to the location in system (PCI memory) space where the initialization code resides.
8. The host then sets the PCI control register master enable bit in the MPC8240 to allow the local processor reset vector fetch (stalled in step 3) to initiate a read from the translated PCI location (as set up in step 7).
9. The MPC8240 then completes the pending reset exception fetch from the translated system address and configures the local memory registers (described in Section 4.6, “Memory Interface Configuration Registers”) and the inbound translation registers (ITWR and LMBAR) as described in Section 3.3.3, “Address Translation Registers.”

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Chapter 8
DMA Controller

This chapter describes the DMA controller of the MPC8240—the operation of the two DMA channels, the function of the DMA transfer types, the DMA descriptors' format, and the programming details for the DMA registers and their features.

8.1 DMA Overview

The MPC8240's DMA controller transfers blocks of data independent of the local processor or PCI hosts. Data movement occurs on the PCI and/or memory bus. The MPC8240 has two DMA channels, each with a 64-byte queue to facilitate the gathering and sending of data. Both the local processor and PCI masters can initiate a DMA transfer. Some of the features of the MPC8240 DMA unit are:

- Two DMA channels (0 and 1)
- Both channels accessible by processor core and remote PCI masters
- Misaligned transfer capability
- Chaining mode (including scatter gathering)
- Direct mode
- Interrupt on completed segment, chain, and error conditions
- Four DMA transfer types:
  - — Local memory to local memory
  - — PCI memory to PCI memory
  - — PCI memory to local memory
  - — Local memory to PCI memory

The DMA controller functions as a PCI agent relative to the other internal resources of the MPC8240.

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Figure 8-1 provides a block diagram of the MPC8240 DMA unit.

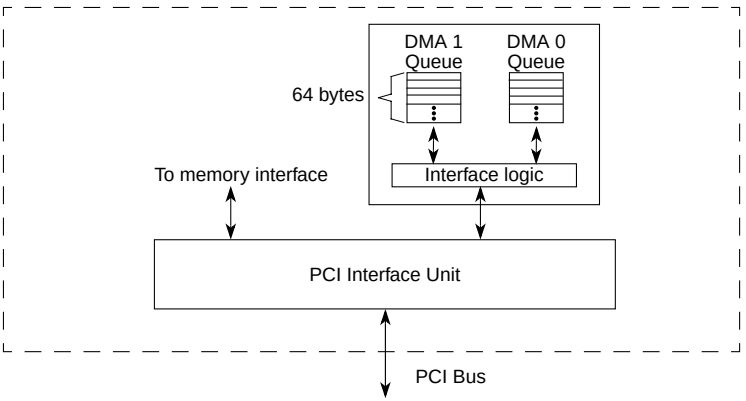

Figure 8-1. DMA Controller Block Diagram

8.2 DMA Register Summary

There are two complete sets of DMA registers on the MPC8240—one for channel 0 and one for channel 1.

The DMA registers of the MPC8240 comprise part of the MPC8240 embedded utilities and are memory mapped. The base addresses for the DMA registers are determined by the PCSRBAR for accesses from PCI memory space and the EUMBBAR for accesses from local memory. See Section 3.4, “Embedded Utilities Memory Block (EUMB),” for more information.

The two DMA channels on the MPC8240 are identical, except that the registers for channel 0 are located at offsets 0x100 and 0x0_1100, and the registers for channel 1 are located at offsets 0x200 and 0x0_1200. Throughout this chapter, the registers are described by a singular acronym (for example, DMR stands for the mode register for either channel 0 or channel 1). Table 8-1 summarizes the DMA registers on the MPC8240. All DMA registers are 32 bits wide and are accessible from the processor or remote PCI masters in both host and agent mode as shown.

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Table 8-1. DMA Register Summary

PCI Memory Offset	Local Memory Offset	Register Name	Description
0x100	0x0_1100	DMA 0 mode register (DMR)	Allows software to setup up different DMA modes and interrupt enables
0x104	0x0_1104	DMA 0 status register (DSR)	Tracks DMA processes and errors
0x108	0x0_1108	DMA 0 current descriptor address register (CDAR)	Contains the location of the current descriptor to be loaded
0x110	0x0_1110	DMA 0 source address register (SAR)	Contains the source address from which data will be read
0x118	0x0_1118	DMA 0 destination address register (DAR)	Contains the destination address to which data will be written
0x120	0x0_1120	DMA 0 byte count register (BCR)	Contains the number of bytes to transfer
0x124	0x0_1124	DMA 0 next descriptor address register (NDAR)	Contains the next descriptor address
0x200	0x0_1200	DMA 1 mode register (DMR)	Allows software to setup up different DMA modes and interrupt enables
0x204	0x0_1204	DMA 1 status register (DSR)	Tracks DMA processes and errors
0x208	0x0_1208	DMA 1 current descriptor address register (CDAR)	Contains the location of the current descriptor to be loaded
0x210	0x0_1210	DMA 1 source address register (SAR)	Contains the source address from which data will be read
0x218	0x0_1218	DMA 1 destination address register (DAR)	Contains the destination address to which data will be written
0x220	0x0_1220	DMA 1 byte count register (BCR)	Contains the number of bytes to transfer
0x224	0x0_1224	DMA 1 next descriptor address register (NDAR)	Contains the next descriptor address

8.3 DMA Operation

The DMA controller operates in two modes—direct and chaining. In direct mode, the software is responsible for initializing the source address register (SAR), destination address register (DAR), and byte count register (BCR). In chaining mode, the software must first build descriptors segments in local or remote memory. Then the current descriptor address register (CDAR) is initialized to point to the first descriptor in memory. In both modes, setting the channel start bit in the DMA mode register (DMR) starts the DMA transfer.

The DMA controller supports misaligned transfers for both the source and destination addresses. It gathers data beginning at the source address and aligns it accordingly before sending it to the destination address. The DMA controller assumes that the source and

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destination addresses are valid PCI or local memory addresses. If MCCR2[RMW_PAR] is cleared, there is no penalty for misaligned transfers. As such, misaligned transfers do not affect bandwidth.

All local memory read operations are non-pipelined cache line reads (32 bytes). The DMA controller selects the valid data bytes within a cache line when storing in its queue. Writing to local memory depends on the destination address and the number of bytes transferred. The DMA controller attempts to write cache lines (non-pipelined) if the destination address is aligned on a 32-byte boundary. Otherwise, partial cache line writes are performed.

PCI memory read operations depend on the PRC bits in the DMR, the source address, and the number of bytes transferred. The DMA controller attempts to read a cache line (32 bytes) whenever possible. All PCI reads are whole beat reads (4 bytes) except when the DMR[SAHE] bit is set (see Table 8-3). Internally, the DMA engine determines the valid bytes within a read and stores them into the queue accordingly.

Writing to PCI memory depends on the destination address and the number of bytes transferred. PCI Write-and-Invalidate operations are performed only if a full cache line is being transferred, the PCI command status register (PCSR) bit 4 (memory write and invalidate) is set, and the PCI cache line size register is set to 0x08 (32-byte cache size). Otherwise, write operations are performed.

The internal DMA protocols operate on a cache line basis, so the MPC8240 always attempts to perform transfers that are the size of a cache line. The only possible exceptions are the first or last transfer. To further enhance performance, the protocols also allow for multiple-cache-line streaming operation in which more than one cache line can be transferred at one time. Therefore, maximum performance is achieved when the initial address of a DMA transfer is aligned to a cache-line boundary.

8.3.1 DMA Direct Mode

In direct mode, the DMA controller does not read descriptors from memory but instead uses the current parameters in the DMA registers to start a DMA process. The DMA transfer is finished after all bytes specified in the BCR have been transferred, or an error condition has occurred. The initialization steps for a DMA transfer in direct mode are as follows:

1. Poll the CB in the DSR to make sure the DMA channel is idle.
2. Initialize the SAR, DAR, and BCR.
3. Initialize the CTT bit in the CDAR to indicate the type of transfer.
4. Initialize the CTM bit in the DMR to indicate direct mode. Other control parameters in the DMR can also be initialized here, if necessary.
5. Clear and then set the CS bit in the DMR to start the DMA transfer.

Note that the DMA registers used for setting up the descriptors in chaining mode also have some implications in direct mode.

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In direct mode, the DMA controller has the ability to hold the destination address or the source address to a fixed value for every transfer. When the DAHE bit is set, the destination address is held, and the DAHTS bit indicates the size used for the transfer. When the SAHE bit is set, the source address is held and the SAHTS bit indicates the size used for transfer.

Note that PCI reads from local memory always check the PCI-to-system memory read buffers (PCMRB) for an address hit. If there is an address match, the data is read directly from the buffer instead of local memory. Because the DMA controller functions as a PCI device on the MPC8240 this address checking also occurs for DMA reads from local memory. Thus, when SAHE is set, DMA transfers from local memory (local-to-local or local-to-PCI) check the PCMRBs for a hit on every transfer. In this case, after the first read from memory, one of the PCMRBs will result in a hit on-chip, and the same data is read from the PCMRB every time (the access is not performed to memory). Thus, if data at the actual source address is changing, the DMA controller does not read the changed data. Refer to Section 12.1.3, “PCI/Local Memory Buffers,” for more information about the PCMRBs.

Only one of DAHE or SAHE may be set at one time. These bits are described in Table 8-3.

8.3.2 DMA Chaining Mode

In chaining mode, the DMA controller loads descriptors from memory prior to a DMA transfer. The DMA controller begins the transfer according to the descriptor information loaded for the segment. Once the current segment is finished, the DMA controller reads the next descriptor from memory and begins another DMA transfer. The process is finished if the current descriptor is the last one in memory, or an error condition has occurred.

DMA chaining mode can be used to implement scatter gathering. In scatter gathering with the MPC8240, a group of descriptors can transfer (scatter) data from a contiguous space of memory to a non-contiguous destination or, likewise, data from a non-contiguous destination can be gathered to a contiguous region of memory.

NOTE:

Source and destination address hold is not supported in chaining mode.

8.3.2.1 Basic Chaining Mode Initialization

The initialization steps for a DMA transfer in chaining mode are as follows:

1. Build descriptor segments in memory. Refer to the Section 8.6, “DMA Descriptors for Chaining Mode,” for more information.
2. Poll the CB bit in the DSR to make sure the DMA channel is idle.
3. Initialize the CDAR to point to the first descriptor in memory.
4. Initialize the CTM bit in the DMR to indicate chaining mode. Other control parameters in the DMR can also be initialized here if necessary.
5. Clear and then set the CS bit in the DMR to start the DMA transfer.

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If software dynamically adds more descriptors to a chain that is finished or currently in progress, the CC bit should be set to restart the transferring process starting at the current descriptor address.

8.3.2.2 Periodic DMA Feature

Periodic DMA is a feature that allows a DMA process to be repeated over and over again with the same parameters while in chaining mode. This feature has potential use in applications that require periodic movement of data. The MPC8240 uses two of the timers in the EPIC unit to automatically signal the DMA channels to start a DMA process, without the use of the processor interrupt. In this mode, timer 2 automatically signals DMA channel 0, and timer 3 automatically signals DMA channel 1. The following sequence describes the steps to set up the periodic DMA feature:

1. Set up timer 2 (and/or timer 3) with the mask bit set (when the timer counts down, no interrupt is generated to the processor). Program the timer to operate at the appropriate rate and clear the CI bit in the corresponding GTBCR. Choose a rate for the timer longer than the time required to complete transferring the DMA chain; otherwise, unpredictable operation occurs. Note that the DMA controller services the timer's request only if the DMA controller is in the idle state (CB bit is cleared). If the timer's request occurs while the DMA controller is busy, then the request is ignored.
2. Program the DMA channel to operate in chaining mode (described in Section 8.3.2.1, "Basic Chaining Mode Initialization").
3. Enable periodic DMA by setting the PDE bit in the DMR.

When the timer first expires, the DMA hardware begins the data movement. In this mode, the current descriptor address is automatically saved for later use. When the timer expires the second time, the DMA reloads the saved current descriptor address into the CDAR and restarts. This process continues until an error condition occurs, or the timer is stopped.

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8.3.3 DMA Operation Flow

Figure 8-2 shows a general flow diagram for the operation of the DMA controller on the MPC8240.

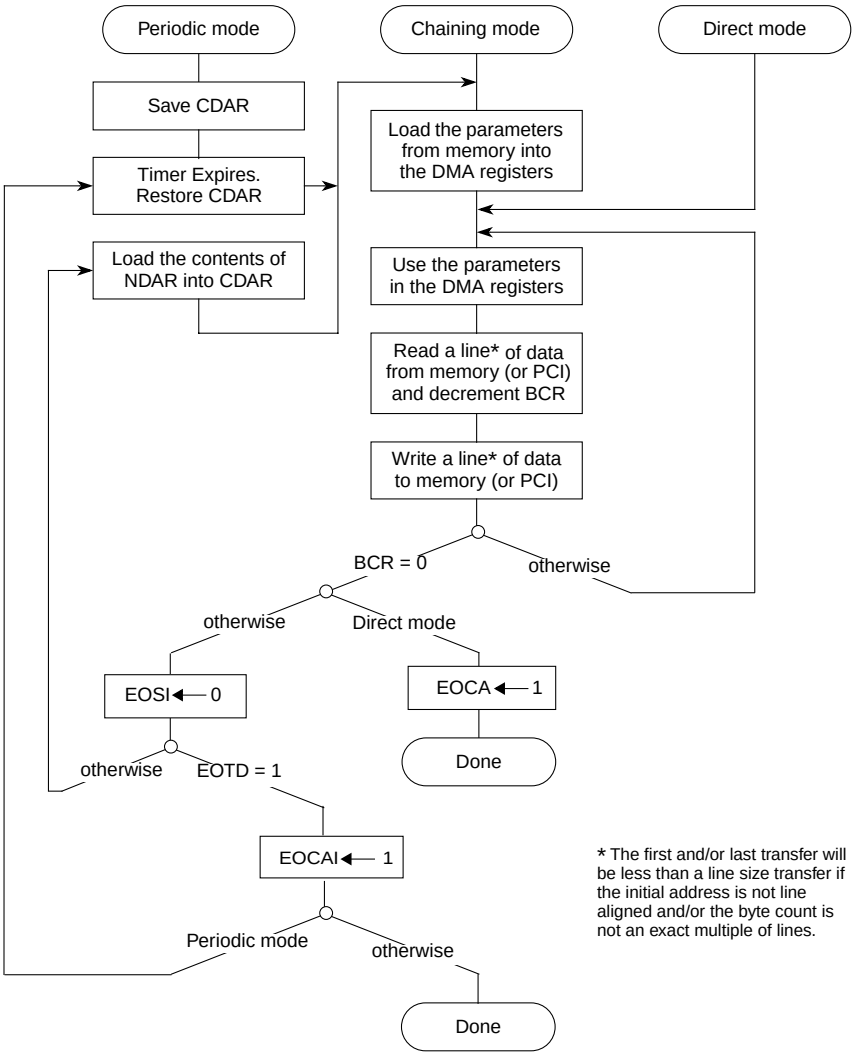
Periodic mode
Chaining mode
Direct mode
Save CDAR
Load the parameters from memory into the DMA registers
Timer Expires. Restore CDAR
Load the contents of NDAR into CDAR
Use the parameters in the DMA registers
Read a line* of data from memory (or PCI) and decrement BCR
Write a line* of data to memory (or PCI)
BCR = 0
otherwise
otherwise
Direct mode
EOSI ← 0
EOCA ← 1
Done
otherwise
EOTD = 1
EOCAI ← 1
Periodic mode
otherwise
Done
* The first and/or last transfer will be less than a line size transfer if the initial address is not line aligned and/or the byte count is not an exact multiple of lines.

Figure 8-2. DMA Controller General Flow

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8.3.4 DMA Coherency

Each DMA channel contains a 64-byte transfer queue. No address snooping occurs in these queues. It is possible that certain data could be posted in these queues and not be visible to the rest of the system while a DMA transfer is in progress. Therefore, software must enforce coherency of the region being transferred during the DMA process.

Snooping of the processor data cache is selectable during DMA transactions. A snoop bit (SNEN) is provided in the CDAR and the next descriptor address register (NDAR) which allows software to control whether the processor cache is snooped. This bit is described in Section 8.7.3, “Current Descriptor Address Registers (CDARs),” and Section 8.7.8, “Next Descriptor Address Registers (NDARs),” respectively.

The MPC8240 architecture assumes that all of the local or host memory is prefetchable including Port X. Note that this results in multiple reads occurring to the same location on the memory interface and Port X.

8.3.5 DMA Performance

The arbitration logic between the DMA controller and other PCI masters is clocked by the PCI clock. However, the DMA controller operates on the memory bus clock, and it communicates to local memory through the central control unit (CCU) that is also clocked by the memory bus clock during transactions with the memory controller. This difference in clocking introduces time delays between the time domains of the PCI devices and the CCU. The phase of the PCI clock relative to the memory bus clock causes latency between the time the DMA controller is programmed to start a transaction and the time the data is actually returned.

Additionally, care must be taken when polling the DMA registers. Access to any of the system registers (configuration and runtime registers) on the MPC8240 temporarily interrupt a DMA stream. Thus, if the processor polls the DMA channel busy bit in the DSR while a DMA transfer is in progress, the DMA transfer is temporarily interrupted, and the performance of the DMA transfer is drastically reduced. To obtain the best performance, the interrupt features of the DMA controller should be used for signalling conditions such as channel complete to the processor.

DMA accesses to local memory may require cache coherency with the processor; such accesses require snooping on the peripheral logic bus. However, snoop hits from the peripheral logic bus (from the L1 cache) for DMA accesses degrade DMA performance. To minimize this effect, the corresponding areas of memory in the processor cache(s) should be flushed prior to initiating the DMA transfers. The arbitration priorities described in Section 12.2, “Internal Arbitration,” show the effect of snooping on the priorities for access to the processor/memory data bus.

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Another factor that can affect DMA performance is access to the PCI bus. For more information on the DMA arbitration boundaries for the PCI bus, see Section 7.2.1, “Internal Arbitration for PCI Bus Access.”

8.4 DMA Transfer Types

The DMA controller supports four types of transfer—PCI to PCI; PCI to memory; memory to PCI; and memory to memory. All data is temporarily stored in a 64-byte DMA queue before transmission.

8.4.1 PCI to PCI

For PCI memory to PCI memory transfers, the DMA controller begins by reading data from PCI memory space and storing it in the DMA queue. When the source and destination addresses are aligned, the DMA transfer occurs after 64 bytes of data have been stored in the queue. When the source and destination addresses are misaligned, the DMA transfer occurs after 32 bytes of data have been stored in the queue. For the last transfer, data in the queue can be less than 32 bytes. The DMA controller begins writing data to PCI memory space beginning at the destination address. The process is repeated until there is no more data to transfer, or an error condition has occurred on the PCI bus.

8.4.2 PCI to Local Memory

For PCI memory to local memory transfers, the DMA controller initiates reads on the PCI bus and stores the data in the DMA queue. When at least 32 bytes of data is in the queue, a local memory write is initiated. The DMA controller stops the transferring process either when there is an error condition on the PCI bus or local memory interface, or when no data is left to transfer. Reading from PCI memory and writing to local memory can occur concurrently.

8.4.3 Local Memory to PCI

For local memory to PCI memory transfers the DMA controller initially fetches data from local memory into the DMA queue. As soon as the first data arrives into the queue, the DMA engine initiates write transactions to PCI memory. The DMA controller stops the transferring process either when there is an error on the PCI bus or local memory interface, or when no data is left to transfer. Reading from local memory and writing to PCI memory can occur concurrently.

8.4.4 Local Memory to Local Memory

For local memory to local memory transfers, the DMA controller begins reading data from local memory and stores it in the DMA queue. When the source and destination addresses are aligned, the DMA transfer occurs after 64 bytes of data have been stored in the queue.

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When the source and destination addresses are misaligned, the DMA transfer occurs after 32 bytes of data have been stored in the queue. For the last transfer, data in the queue can be less than 32 bytes. The DMA controller begins writing data to local memory space beginning at the destination address. The process is repeated until there is no more data to transfer or an error condition occurs while accessing memory.

8.5 Address Map Interactions

Because of the flexibility of the MPC8240's DMA controller, certain interactions can occur related to the specific address map and mode in which MPC8240 is operating. Refer to Chapter 13, "Error Handling," for information on the reporting of these error conditions.

8.5.1 Attempted Writes to Local ROM/Port X Space

If the MPC8240 is in either host or agent mode, CDAR[CCT] indicates that the transferred address is for local memory, and the address falls between 0xFF00_0000 and 0xFFFF_FFFF, only read operations are allowed. Attempts to program the DMA controller to write to this space (comprising the local ROM/Port X space) under these conditions results in a Flash write error and DSR[LME] is set if ErrDR1[5] is set before the DMA unit completes transferring the data. (For a DMA transfer with a small byte count, less than a cache line, it is possible for the DMA posted write to the CCU buffer to complete prior to the start of the actual write to local memory.) Additionally, this error condition causes the assertion of the internal $\overline{mcp}$ signal, and a machine check exception (if enabled).

See Chapter 13, "Error Handling," for more information about the internal $\overline{mcp}$ signal.

8.5.2 Host Mode Interactions

The following subsections describe cases of interactions with the host mode address maps.

8.5.2.1 PCI Master Abort when PCI Bus Specified for Lower 2-Gbyte Space

If the MPC8240 is in host mode and a transferred address falls within the lower 2-Gbyte space (0x0000_0000 to 0x7FFF_FFFF) on the PCI bus (specified by CDAR[CTT]), then the MPC8240 issues the transaction to the PCI bus with that address. However, this address space is reserved for the host controller; therefore, no PCI target responds to the transaction, and the transaction terminates with a PCI master abort and the PE bit in DMR is set.

8.5.2.2 Address Alias to Lower 2-Gbyte Space

If the MPC8240 is in host mode, the CDAR[CTT] indicates that the transferred address is for local memory and the address falls between 0x8000_0000 and 0xFEFF_FFFF, then the transaction is issued to local memory and the address is aliased to the lower 2-Gbyte space.

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8.5.2.3 Attempted Reads from ROM on the PCI Bus—Host Mode

If the MPC8240 is in host mode, CDAR[CTT] indicates that the transferred address is for local ROM space and the MPC8240 is configured for ROM on the PCI bus, then the transaction is performed to the local ROM interface. Unknown data will be returned. (This is considered a programming error.)

8.5.2.4 Attempted Reads from ROM on the Memory Bus

If the MPC8240 is in host mode, the CDAR[CTT] indicates that the transferred address is for PCI ROM space and the MPC8240 is configured for ROM on the local memory interface, then the transaction is issued to the PCI bus. The transaction will result in either a master abort (and DSR[PE] is set) or an access to a configured device in the ROM address space on the PCI bus.

8.5.3 Agent Mode Interactions

The following subsections describe interactions with the agent mode address maps.

8.5.3.1 Agent Mode DMA Transfers for PCI

When CDAR[CTT] indicates that the transferred address is for PCI, any address can be issued within the 32-bit address space. If the software running on an MPC8240 configured as an agent is aware of the system address map, it can perform DMA transfers with the untranslated system address.

Alternatively, the MPC8240 agent DMA driver does not need to be aware of the system memory map, and it can rely on address translation to be performed by the ATU. In this case, transaction addresses should be programmed to fall within the outbound memory window.

8.5.3.2 Accesses to Outbound Memory Window that Overlaps 0xFE00_00 – 0xFEEF_FFFF

For agent mode, if the outbound memory window is programmed to overlap the PCI's I/O space (0xFE0x_xxxx – 0xFEBx_xxxx), PCI configuration space (0xFECx_xxxx – 0xFEDx_xxxx), or PCI interrupt acknowledge space (0xFEEx_xxxx), then a DMA transaction to these address spaces results in a translated outbound address. Note that this differs from a processor-generated transaction. In the case of a processor-generated transaction to these spaces, these address ranges appear as holes in the outbound translation window.

8.5.3.3 Attempted Accesses to Local ROM when ROM is on PCI

If the CDAR[CTT] indicates that the transferred address is for local ROM space and the ROM is located on PCI, then the transaction is issued to local memory and results in unknown data returned.

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8.5.3.4 Attempted Access to ROM on the PCI Bus—Agent Mode

If the CDAR[CTT] indicates that the transferred address is for ROM on the PCI bus and the ROM is located locally, then the transaction is issued to the PCI bus and results in a master abort (and DSR[PE] is set) or a completed transaction, depending on whether a device is configured on the PCI bus in that address space.

8.6 DMA Descriptors for Chaining Mode

For DMA chaining mode, DMA descriptors are constructed in either local or PCI memory and linked together by the next descriptor field. The descriptor contains information for the DMA controller to transfer data. Software must ensure that each segment descriptor is aligned on an 8-word boundary. The last descriptor in memory must have the EOTD bit set in the next descriptor field, indicating that this is the last descriptor in memory.

Software initializes the CDAR to point to the first descriptor in memory. The DMA controller traverses through the descriptor chain until the last descriptor is read. For each descriptor in the chain, the DMA controller starts a new DMA transfer with the control parameters specified by the descriptor.

Table 8-2 summarizes the fields of DMA descriptors.

Table 8-2. DMA Descriptor Summary

Descriptor Field	Description
Source address	Contains the source address of the DMA transfer. When the DMA controller reads the descriptor from memory, this field is loaded into the SAR as described in Table 8-4.
Destination address	Contains the destination address of the DMA transfer. When the DMA controller reads the descriptor from memory, this field is loaded into the DAR as described in Table 8-4.
Next descriptor address	Points to the next descriptor in memory. When the DMA controller reads the descriptor from memory, this field is loaded into the NDAR as described in Table 8-4. If the current descriptor is the last descriptor in memory, then the EOTD bit in this descriptor field must be set.
Byte count	Contains the number of bytes to transfer. When the DMA controller reads the descriptor from memory, this field is loaded into the BCR as described in Table 8-8.

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Figure 8-3 shows how the DMA descriptors in memory are chained together.

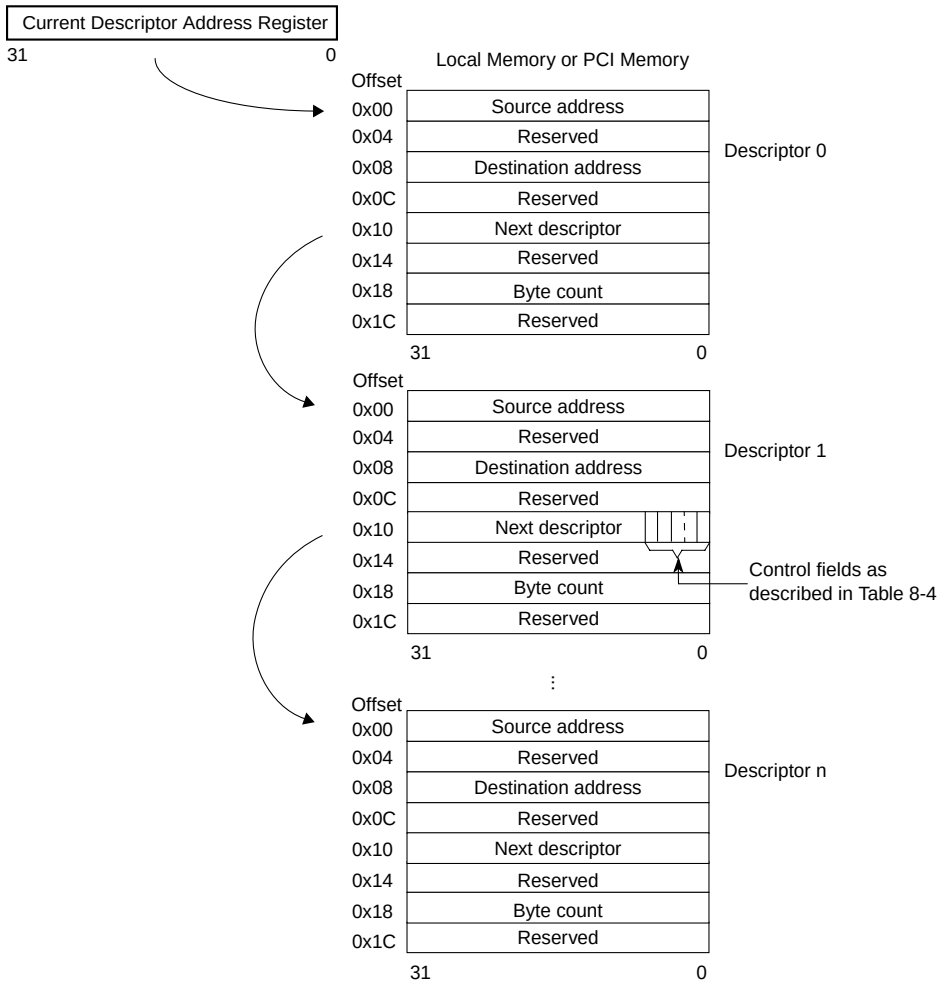

Figure 8-3. Chaining of DMA Descriptors in Memory

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8.6.1 Descriptors in Big-Endian Mode

In big-endian byte ordering mode(MSR[LE] = 0), the descriptors in local memory should be programmed with data appearing in ascending significant byte order.

For example, a big-endian mode descriptor's data structure is as follows:

```
struct {
        double a;       /* 0x1122334455667788 double word */
        double b;       /* 0x55667788aabbccdd double word */
        double c;       /* 0x8765432101234567 double word */
        double d;       /* 0x0123456789abcdef double word */
} Descriptor;

Results: Source Address = 0x44332211 <MSB..LSB>
        Destination Address = 0x88776655 <MSB..LSB>
        Next Descriptor Address = 0x21436587 <MSB..LSB>
        Byte Count = 0x67452301 <MSB..LSB>
```

Note that the descriptor `struct` must be aligned on an 8-word (32-byte) boundary.

8.6.2 Descriptors in Little-Endian Mode

In little-endian byte ordering mode(MSR[LE] = 1), the descriptor in local memory should be programmed with data appearing in descending significant byte order.

For example, a little-endian mode descriptor's data structure is as follows:

```
struct {
        double a;       /* 0x8877665544332211 double word */
        double b;       /* 0x1122334488776655 double word */
        double c;       /* 0x7654321012345678 double word */
        double d;       /* 0x0123456776543210 double word */
} Descriptor;

Results: Source Address = 0x44332211 <MSB..LSB>
        Destination Address = 0x88776655 <MSB..LSB>
        Next Descriptor Address = 0x12345678 <MSB..LSB>
        Byte Count = 0x76543210 <MSB..LSB>
```

Note that the descriptor struct must be aligned on an 8-word (32-byte) boundary.

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8.7 DMA Register Descriptions

The following sections describe the DMA controller registers and their bit settings in detail. Note that the PCI address offset is listed as part of the register descriptions table titles. For the local memory offsets, see Table 8-1.

8.7.1 DMA Mode Registers (DMRs)

The DMRs allow software to start the DMA transfer and to control various DMA transfer characteristics. Figure 8-4 shows the bits in the DMRs.

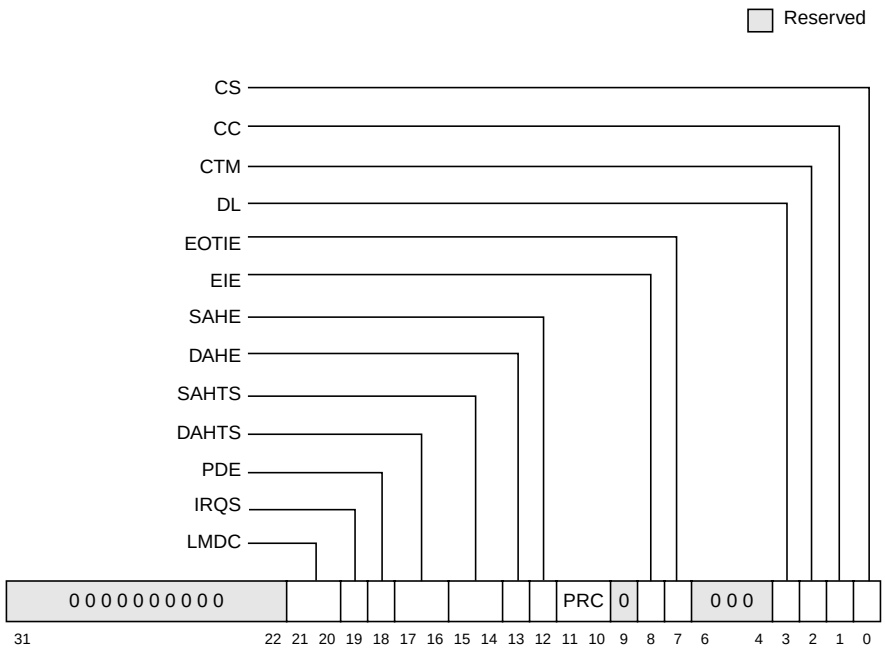

Figure 8-4. DMA Mode Register (DMR)

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Table 8-3 describes the bit settings for the DMRs.

Table 8-3. DMR Field Descriptions—Offsets 0x100, 0x200

Bits	Name	Reset Value	R/W	Description
31–22	—	0	R	Reserved
21–20	LMDC	00	RW	Local memory delay count. This field controls the delay between the DMA transfer of each cache line (32 bytes) access to local memory. The delay value is the time from the last successful DMA transfer until the next request occurs to local memory. Increasing this value to something greater than 0b00 gives a greater probability of PCI accesses gaining arbitration to the shared processor/memory bus while a DMA transfer is in progress. Refer to Section 12.2.1, “Arbitration Between PCI and DMA Accesses to Local Memory,” for more information. 00 4 sys_logic_clk cycles 01 8 sys_logic_clk cycles 10 16 sys_logic_clk cycles 11 32 sys_logic_clk cycles
19	IRQS	0	RW	Interrupt steer 0 Routes all DMA interrupts to the processor core through the internal $\overline{\text{int}}$ mechanism and the EPIC unit. 1 Routes all DMA interrupts to the PCI bus through the external $\overline{\text{INTA}}$ signal.
18	PDE	0	RW	Periodic DMA enable. Applies only to chaining mode. Otherwise, it is ignored. Refer to Section 8.3.2.2, “Periodic DMA Feature,” for more information. 0 Disables periodic DMA restart 1 Allows hardware to periodically restart the DMA process.
17–16	DAHTS	00	RW	Destination address hold transfer size. Applies only to direct mode (not used in chaining mode). Indicates the transfer size used for each transaction when the DAHE bit is set. The BCR value must be in multiples of this size and the DAR value must be aligned based on this size. 00 1 byte 01 2 bytes 10 4 bytes 11 8 bytes
15–14	SAHTS	00	RW	Source address hold transfer size. Applies only to direct mode (not used in chaining mode). Indicates the transfer size used for each transaction when the SAHE bit is set.The BCR value must be in multiples of this size and the SAR value must be aligned based on this size. 00 1 byte 01 2 bytes 10 4 bytes 11 8 bytes
13	DAHE	0	RW	Destination address hold enable (direct mode only). Applies only to direct mode (not used in chaining mode). Allows the DMA controller to hold the destination address to a fixed value for every transfer. The size used for the transfers is indicated by DAHTS. The MPC8240 only supports aligned transfers for this feature. Only one of DAHE or SAHE may be set at one time. 0 Disables the destination address hold feature 1 Enables the destination address hold feature
12	SAHE	0	RW	Source address hold enable (direct mode only). Applies only to direct mode (not used in chaining mode). Allows the DMA controller to hold the source address to a fixed value for every transfer. The size used for the transfers is indicated by SAHTS. The MPC8240 only supports aligned transfers for this feature. Only one of DAHE or SAHE may be set at one time. 0 Disables the source address hold feature 1 Enables the source address hold feature

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Table 8-3. DMR Field Descriptions—Offsets 0x100, 0x200 (Continued)

Bits	Name	Reset Value	R/W	Description
11–10	PRC	00	RW	PCI Read Command. Indicates the types of PCI read command to be used. 00 PCI Read 01 PCI Read-line 10 PCI Read-multiple 11 Reserved
9	—	0	R	Reserved
8	EIE	0	RW	Error interrupt enable. Interrupt mechanism used depends on the setting of the IRQS bit. 0 Disables error interrupts 1 Generates an interrupt to the processor core, through the internal $\overline{\text{int}}$ mechanism and the EPIC unit, if there is a memory or PCI error during a DMA transfer (signalled by the setting of LME or PE in the DSR).
7	EOTIE	0	RW	End-of-transfer interrupt enable. Interrupt mechanism used depends on the setting of the IRQS bit. 0 Disables end-of-transfer interrupts 1 Generates an interrupt at the completion of a DMA transfer. (that is, NDAR[EOTD] bit is set). For chained DMA, the interrupt is driven active at the end of the last segment. For periodic DMA, the interrupt is driven at the end of each periodic transfer event.
6–4	—	000	R	Reserved
3	DL	0	RW	Descriptor location 0 The descriptor is located in the local memory space. 1 The descriptor is located in the PCI memory space.
2	CTM	0	RW	Channel transfer mode 0 Chaining mode. See Section 8.3.2, “DMA Chaining Mode.” 1 Direct DMA mode. Software is responsible for placing all the required parameters into the necessary registers to start the DMA process. See Section 8.3.1, “DMA Direct Mode.”
1	CC	0	RW	Channel continue. This bit applies only to chaining mode and is cleared by the MPC8240 after every descriptor read. It is typically set after software dynamically adds more descriptors to a chain that is currently in progress or to a finished chain. Note that it is not advisable to remove descriptors by setting this bit because there is no deterministic way to predict when the DMA controller will read a specific descriptor. 0 Channel stopped 1 The DMA transfer will restart the transferring process starting at the current descriptor address (in CDAR).
0	CS	0	RW	Channel start. This bit is toggled by software. 0 to 1 transition when the channel is not busy (DSR[CB] = 0) starts the DMA process. If the channel is busy and a 0 to 1 transition occurs, then the DMA channel restarts from a previous halt condition. 1 to 0 transition when the channel is busy (DSR[CB] = 1) halts the DMA process. Note that in chaining mode, it is not necessary to halt the channel to modify a descriptor because descriptors can be modified by setting the DMR[CC] bit. Nothing happens if the channel is not busy and a 1 to 0 transition occurs.

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The values in the PRC field are used as follows:

- If PRC = 00 (PCI read), then all DMA reads from PCI use the PCI read command.
- If PRC = 01 (PCI read line), then the PCI read line command is used if the PCLSR (see Section 4.2.5, “PCI Cache Line Size—Offset 0x0C) is programmed for 32-byte cache lines, and the current DMA transfer is for at least two 32-bit transactions. Otherwise, PCI read commands are used.
- If PRC = 10 (PCI read multiple), then the PCI read multiple command if used if the PCLSR is programmed for 32-byte cache lines, the current DMA transfer is aligned on a cache line address, and more than one full cache line of data is to be transferred. Otherwise, if the current DMA transfer is for at least two 32-bit transactions (and less than or equal to one cache line), then the read line command is used. If the conditions for using the PCI read line command above are not met, then the PCI read command is used.

8.7.2 DMA Status Registers (DSRs)

The DSRs report various DMA conditions during and after the DMA transfer. Writing a 1 to a set bit clears the bit. Software attempting to determine the source of interrupts should always perform a logical AND function between the bits of the DSR and their corresponding enable bits in the DMR and CDAR. Figure 8-5 shows the bits in the DSRs.

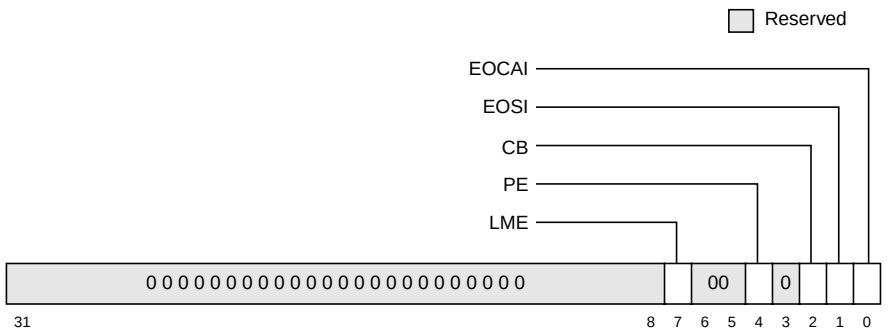

Figure 8-5. DMA Status Register (DSR)

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Table 8-4 describes the bit settings for the DSRs.

Table 8-4. DSR Field Descriptions—Offsets 0x104, 0x204

Bits	Name	Reset Value	R/W	Description
31–8	—	All 0s	R	Reserved
7	LME	0	R/W Write1 clears	Local memory error 0 No local memory error. When this bit is set, it can only be cleared by writing a 1 to it or by a hard reset. 1 A memory error condition occurred during the DMA transfer. This bit mirrors the ErrDR1bits 2, 3, 5. and 6 (see Section 4.8.2, “Error Enabling and Detection Registers.”) Software should set the corresponding enable bits in the error enabling register. When an error is detected, software should clear both the LME bit and the bits in the error detection register. If DMR[EIE] = 1, an interrupt is generated.
6–5	—	00	R	Reserved
4	PE	0	R/W Write1 clears	PCI error 0 No PCI error. When this bit is set, it can only be cleared by writing a 1 to it or by a hard reset. 1 A master or target abort condition or a read parity error occurred on the PCI bus during the DMA transfer. If DMR[EIE] = 1, an interrupt is generated.
3	—	0	R	Reserved
2	CB	0	R	Channel busy 0 Channel not busy. This bit is cleared by the MPC8240 as a result of an error or when the DMA transfer is finished. 1 A DMA transfer is currently in progress.
1	EOSI	0	R/W Write1 clears	End-of-segment interrupt 0 No end-of-segment condition. When this bit is set, it can only be cleared by writing a 1 to it or by a hard reset. 1 If CDAR[EOSIE] = 1 and the block of data has finished transferring, this bit is set and an interrupt is generated.
0	EOCAI	0	R/W Write1 clears	End-of-chain/direct interrupt 0 DMA transfer not finished. When this bit is set, it can only be cleared by writing a 1 to it or by a hard reset. 1 If DMR[EOTIE] = 1 and the last DMA transfer is finished, either in chaining or direct mode, this bit is set and an interrupt is generated.

8.7.3 Current Descriptor Address Registers (CDARs)

The CDARs contains the current address of the descriptor in memory to be loaded, one for each DMA channel. In chaining mode, software must initialize this register to point to the first descriptor in memory.

After transferring data defined by the first descriptor, if the EOTD bit in the next descriptor address register (NDAR) is not set, the DMA controller loads the contents of the NDAR into the CDAR and begins transferring data based on the next descriptor in memory. If the NDAR[EOTD] = 1, then the DMA transfer is finished. The SNEN, EOSIE, and CTT bits are used in both chaining and direct modes. In agent mode, if the descriptor is located in PCI space (DMR[DL] = 1) and the CDA is within the outbound translation window, then the CDA is translated. See Section 3.3.2, “Outbound PCI Address Translation,” for more information.

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Figure 8-6 shows the bits in the CDARs.

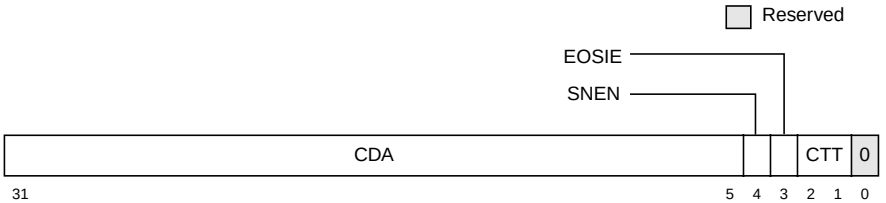

Figure 8-6. Current Descriptor Address Register (CDAR)

Table 8-4 describes the bit settings for the CDARs.

Table 8-5. CDAR Field Descriptions—Offsets 0x108, 0x208

Bits	Name	Reset Value	R/W	Description
31–5	CDA	All 0s	RW	Current descriptor address. Contains the current descriptor address of the buffer descriptor in memory. It must be aligned on an 8-word boundary. These bits are valid only for chaining mode.
4	SNEN	0	RW	Snoop enable. When set, enables snooping of the local processor during DMA transactions. The transaction can be a descriptor fetch or local memory read/write. This bit is valid for both chaining and direct modes. In chaining mode, each descriptor has individually controlled snooping characteristics. 0 Disables snooping 1 Enables processor core snooping for DMA transactions if PICR[NO_SNOOP_EN] = 0. If PICR[NO_SNOOP_EN] = 1, snooping is disabled.
3	EOSIE	0	RW	End-of-segment interrupt enable. Interrupt mechanism used depends on the setting of DMR[IRQS]. This bit is valid only for chaining mode. 0 End-of-segment interrupt disabled 1 Generates an interrupt if the DMA transfer for the current descriptor is finished.
2–1	CTT	00	RW	Channel transfer type. These two bits specify the type/direction of the DMA transfer. These bits are valid for both chaining and direct modes. 00 Local memory to local memory transfer 01 Local memory to PCI transfer 10 PCI to local memory transfer 11 PCI to PCI transfer
0	—	0	R	Reserved

8.7.4 Source Address Registers (SARs)

The SARs indicate the address from which the DMA controller reads data. This address can be either a PCI memory or local memory address. The software has to ensure that this is a valid memory address. In agent mode, all DMA to PCI read transactions are translated if the SAR address is within the outbound translation window. See Section 3.3.2, “Outbound PCI Address Translation,” for more information.

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Figure 8-7 shows the bits in the SARs.

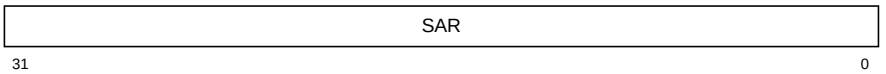

Figure 8-7. Source Address Register (SAR)

Table 8-4 describes the bit settings for the SARs.

Table 8-6. SAR Field Description—Offsets 0x110, 0x210

Bits	Name	Reset Value	R/W	Description
31–0	SAR	All 0s	RW	Source address. This register contains the source address of the DMA transfer. The content is updated by the MPC8240 after every DMA read operation.

8.7.5 Destination Address Registers (DARs)

The DARs indicate the address to which the DMA controller writes data. This address can be either a PCI memory or local memory address. The software has to ensure that this is a valid memory address. In agent mode, all DMA to PCI write transactions are translated if the DAR address is within the outbound translation window. See Section 3.3.2, “Outbound PCI Address Translation,” for more information.

Figure 8-8 shows the bits in the SARs.

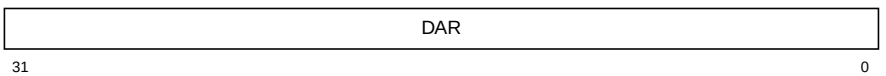

Figure 8-8. Destination Address Register (DAR)

Table 8-4 describes the bit settings for the DARs.

Table 8-7. DAR Field Description—Offsets 0x118, 0x218

Bits	Name	Reset Value	R/W	Description
31–0	DAR	All 0s	RW	Destination address. This register contains the destination address of the DMA transfer. The content is updated by the MPC8240 after every DMA write operation.

8.7.6 Byte Count Registers (BCRs)

The BCRs contain the number of bytes per transfer. The maximum transfer size is 64 Mbytes - 1 byte.

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Figure 8-9 shows the bits in the BCRs.

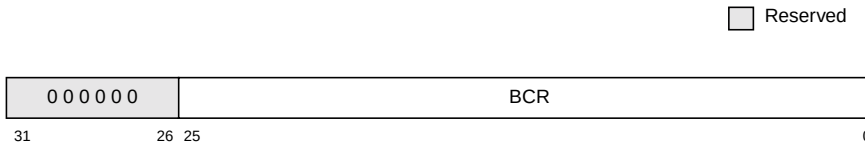

Figure 8-9. Byte Count Register (BCR)

Table 8-8 describes the bit settings for the BCRs.

Table 8-8. BCR Field Descriptions—Offsets 0x120, 0x220

Bits	Name	Reset Value	R/W	Description
31–26	—	All 0s	RW	Reserved
25–0	BCR	All 0s	RW	Byte count. Contains the number of bytes to transfer. The value in this register is automatically decremented by the MPC8240 after each DMA read operation until BCR = 0.

8.7.7 DAR and BCR Values—Double PCI Write

Note that when the DMA controller is programmed for local memory to PCI or PCI-to-PCI memory transfers, certain values programmed in the DAR and BCR can cause the DMA controller to write the last beat of data twice. Although no data corruption occurs and the status register updates normally after the second beat of the double write has completed, care must be taken if the device on the PCI bus is a FIFO-like structure.

The combination of DAR and BCR values that result in the double write can be determined as follows:

(DAR + BCR) mod 0x20 = R,

where R= 0x09–0x0C, 0x11–0x14, or 0x19–0x1C

Example 1: DMA 42 (decimal) bytes from 0x0000_0000 to 0x8000_0000
R = (DAR + BCR) mod 0x20
R = (0x8000_0000 + 0x2A) mod 0x20
R = (2,147,483,648d + 42d) mod 32d
R = 10d = 0x0A
R = 0x0A which is in the range of 0x09–0x0C; therefore, double write of last beat to PCI will occur.

Example 2: DMA 50 (decimal) bytes from 0x0009_0000 to 0x0009_4FE0.
R = (DAR + BCR) mod 0x20
R = (0x0009_4FE0 + 0x32) mod 0x20
R = (610,272d + 50d) mod 32d
R = 18d = 0x12
R = 0x12 which is in the range of 0x11–0x14; therefore, double write of last beat to PCI will occur.

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8.7.8 Next Descriptor Address Registers (NDARs)

The NDARs contain the address for the next descriptor in memory. Software is not expected to initialize this register. This register contains valid information only after the DMA engine has fetched a descriptor that was pointed to by the CDAR. All data bits, with the exception of EOTD, belong to the next descriptor to be loaded and executed. When the data bits are transferred to the CDAR, the bits become effective for the current transfer.

Figure 8-10 shows the bits in the NDARs.

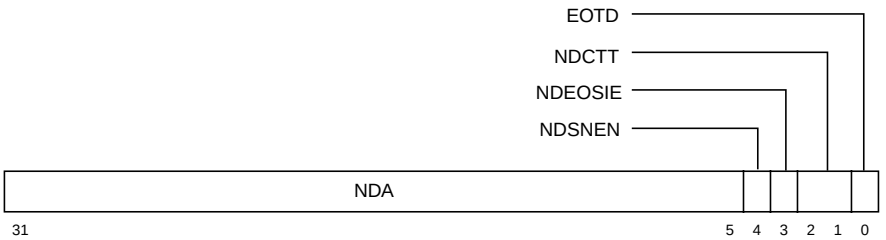

Figure 8-10. Next Descriptor Address Register (NDAR)

Table 8-4 describes the bit settings for the NDARs.

Table 8-9. NDAR Field Descriptions—Offsets 0x124, 0x224

Bits	Name	Reset Value	R/W	Description
31–5	NDA	All 0s	RW	Next descriptor address. Contains the next descriptor address of the buffer descriptor in memory; must be aligned on an 8-word boundary.
4	NDSNEN	0	RW	Next descriptor snoop enable. This bit is valid for both chaining and direct modes. 0 Disables snooping 1 Enables processor core snooping for DMA transactions.
3	NDEOSIE	0	RW	Next descriptor end-of-segment interrupt enable. Interrupt mechanism used depends on the setting of DMR[IRQS]. This bit is valid only for chaining mode. 0 End-of-segment interrupt disabled 1 Generates an interrupt if the DMA transfer for the next descriptor is finished.
2–1	NDCTT	00	RW	Next descriptor channel transfer type. These two bits specify the type/direction of the DMA transfer. These bits are valid for both chaining and direct modes. 00 Local memory to local memory transfer 01 Local memory to PCI transfer 10 PCI to local memory transfer 11 PCI to PCI transfer
0	EOTD	0	RW	End-of-transfer descriptor. This bit is ignored in direct mode. 0 This descriptor is not the last descriptor in memory. 1 Indicates that this descriptor is the last descriptor in memory. If this bit is set, NDAR bits 4, 3, 2, and 1 are ignored and the DMA controller finishes after the current buffer transaction is finished.

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Chapter 9
Message Unit (with I_2O)

The MPC8240 provides a message unit (MU) to facilitate communication between the host processor and peripheral processors. The MPC8240's MU can operate with generic messages and doorbell registers; it also implements an I_2O-compliant interface. This chapter describes both interfaces implemented by the MU and provides the details on the registers used by the MU.

9.1 Message Unit (MU) Overview

An embedded processor is often part of a larger system containing many processors and distributed memory. These processors tend to work on tasks independent of host processors and other peripheral processors in the system. Because of the independent nature of the tasks, it is necessary to provide a communication mechanism between the peripheral processors and the rest of the system. The MU of the MPC8240 provides the following features which can be used for this communication:

- A generic message and doorbell register interface
- An I_2O-compliant interface

The message unit uses the internal $\overline{int}$ and $\overline{\text{INTA}}$ signals to communicate messages to the processor core and the PCI bus. Internal $\overline{int}$ interrupts generated by the DMA unit are first routed to the MU. These collected interrupts are then pooled with the doorbell and I_2O interrupts and routed to the EPIC unit as MU interrupts prior to the generation of the internal $\overline{int}$ to the processor. Note that the EPIC unit only passes internally-generated interrupts to the processor core when pass-through mode is disabled (GCR[M] = 0). See Section 11.4, "EPIC Pass-Through Mode," for more information. Conversely, the MU pools the various sources of $\overline{\text{INTA}}$ (from the DMA unit and MU-generated interrupt conditions) for $\overline{\text{INTA}}$ assertion on the PCI bus.

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9.2 Message and Doorbell Register Programming Model

The message and doorbell registers are described in the following subsections. Note that the interrupt status and interrupt mask bits for the message and doorbell registers are in the OMISR, OMIMR, IMISR, and IMIMR I_2O registers. See Section 9.3.4.1, “PCI-Accessible I2O Registers” and Section 9.3.4.2, “Processor-Accessible I2O Registers,” for more information about these registers.

The outbound message and doorbell registers are used to communicate with a PCI host by asserting the $\overline{\text{INTA}}$ signal on the PCI bus. The PCI host is defined as the device that handles the PCI interrupts.

The message and doorbell registers can also be used to perform peer-to-peer communication such as between multiple MPC8240 devices in a system. In this scenario, only the inbound registers need to be used and should be all mapped to different PCSRBAR locations. Because there is not a host in this scenario, $\overline{\text{INTA}}$ is not generated (and the outbound registers are not used).

9.2.1 Message and Doorbell Register Summary

MPC8240 contains two 32-bit inbound message registers (IMR0 and IMR1) and two 32-bit outbound message registers (OMR0 and OMR1) that function in both host and agent mode.

Table 9-1 summarizes the message registers.

Table 9-1. Message Register Summary

PCI Offset	Local Memory Offset	Acronym	Name
0x050	0x0_0050	IMR0	Inbound message register 0
0x054	0x0_0054	IMR1	Inbound message register 1
0x058	0x0_0058	OMR0	Outbound message register 0
0x05C	0x0_005C	OMR1	Outbound message register 1

The MPC8240 also contains a 32-bit inbound and a 32-bit outbound doorbell register (IDBR and ODBR, respectively). Table 9-2 summarizes the doorbell registers.

Table 9-2. Doorbell Register Summary

PCI Offset	Local Memory Offset	Acronym	Name
0x060	0x0_0060	ODBR	Outbound doorbell register
0x068	0x0_0068	IDBR	Inbound doorbell register

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9.2.2 Message Register Descriptions

The IMRs allow a remote host or PCI master to write a 32-bit value that automatically generates an interrupt to the processor core through the EPIC unit. The OMRs allow the processor core to write an outbound message that automatically causes the outbound interrupt signal $\overline{\text{INTA}}$ to be asserted on the PCI bus. These interrupts can be masked in the IMIMR and OMIMR. When the message registers are written, their corresponding interrupt status bits in the IMISR and OMISR are set. Figure 9-1 shows the bits of the IMRs and OMRs.

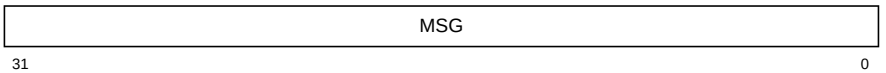

Figure 9-1. Message Registers (IMRs and OMRs)

Table 9-3 shows the bits settings for the IMRs and OMRs.

Table 9-3. IMR and OMR Field Descriptions—Offsets 0x050–0x05C, 0x0_0050–0x0_005C

Bits	Name	Reset Value	R/W	Description
31–0	MSG	Undefined	R/W	The inbound and outbound message registers contain generic message data to be passed between the processor core and remote processors.

9.2.3 Doorbell Register Descriptions

The IDBR allows a remote processor to set a bit in the register from the PCI bus. This, in turn, generates an interrupt to the processor core through the EPIC unit if the interrupt is not masked in IMIMR, or generates $\overline{mcp}$ (if it is not masked in IMIMR). After the local interrupt (or $\overline{mcp}$) is generated, it can only be cleared by the processor core by writing a 1 to the bits that are set in the IDBR. The remote processor can only generate the local interrupt through the IDBR; it cannot clear the interrupt. Figure 9-2 shows the IDBR.

Figure 9-2. Inbound Doorbell Register (IDBR)

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Table 9-4 shows the bit settings for the IDBR.

Table 9-4. IDBR Field Descriptions—Offsets 0x068, 0x0_0068

Bits	Name	Reset Value	R/W	Description
31	MC	0	R/W. A write of 1 from PCI sets the bit; a write of 1 from the processor core clears the bit.	Machine check 0 No machine check 1 Writing to this bit causes the assertion of $\overline{\text{mcp}}$ to the processor core if IMIMR[DMCM] = 0; it also causes IMISR[DMC] to be set.
30–0	DBn	All 0s	R/W. A write of 1 from PCI sets the bit; a write of 1 from the processor core clears the bit.	Inbound doorbell n interrupt, where n is each bit 0 No inbound doorbell interrupt 1 Setting any bit in this register from the PCI bus causes an interrupt to be generated through the $\overline{\text{int}}$ signal to the processor core if IMIMR[IDIM] = 0; it also causes IMISR[IDI] to be set.

Alternatively, theMPC8240 processor core can write to the ODBR, which causes the outbound interrupt signal $\overline{\text{INTA}}$ to be asserted, thus interrupting a remote processor if the interrupt is not masked in OMIMR. When $\overline{\text{INTA}}$ is generated, it can only be cleared by the remote processor (through PCI) by writing a 1 to the bits that are set in the ODBR. The processor core can only generate $\overline{\text{INTA}}$ through the ODBR, and it can not clear this interrupt.

Figure 9-3 shows the ODBR.

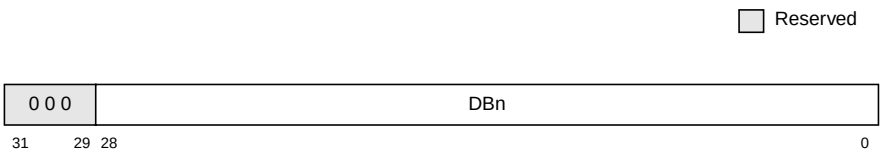

Figure 9-3. Outbound Doorbell Register (ODBR)

Table 9-5 shows the bit settings for the ODBR.

Table 9-5. ODBR Field Descriptions—Offsets 0x060, 0x0_0060

Bits	Name	Reset Value	R/W	Description
31–29	—	000	R	Reserved
28–0	DBn	All 0s	R/W. A write of 1 from the processor core sets the bit; a write of 1 from PCI clears the bit.	Outbound doorbell interrupt n where n is each bit. Writing any bit in this register from the processor core causes an external interrupt ($\overline{\text{INTA}}$) to be signalled if IMIMR[ODIM] = 0; it also causes OMISR[ODI] to be set

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9.3 I_2O Interface

The intelligent input output (I_2O) specification was established in the industry to allow architecture-independent I/O subsystems to communicate with an OS through an abstraction layer. The specification is centered around a message-passing scheme. An I_2O-compliant embedded peripheral (IOP) is comprised of memory, processor, and input/output devices. The IOP dedicates a certain space in its local memory to hold inbound (from the remote processor) and outbound (to the remote processor) messages. The space is managed as memory-mapped FIFOs with pointers to this memory maintained through the MPC8240 I_2O registers.

9.3.1 PCI Configuration Identification

The I_2O specification defines extensions for the PCI bus through which message queues are managed in hardware. A host identifies an IOP by its PCI class code. Table 9-6 provides the configuration information available to the host when the I_2O unit is enabled.

Table 9-6. I_2O PCI Configuration Identification Register Settings

PCI Configuration Offset	Local Memory Offset	Register	Description
0x09	0x09	PCI CFG	PCI configuration—Programming interface code PCI data returned: 0x01
0x0A	0x0A	PCI CFG	PCI configuration—Sub class PCI data returned: 0x00
0x0B	0x0B	PCI CFG	PCI configuration—PCI base class Data returned: 0x0E

See Section 4.2, “PCI Interface Configuration Registers,” for more information on the PCI base class and programming interface codes. The subclass is described in more detail in the PCI specification.

9.3.2 I_2O Register Summary

The MPC8240 I_2O registers are summarized in Table 9-7.

Table 9-7. I_2O Register Summary

PCI Offset	Local Memory Offset	Acronym	Name
0x030	—	OMISR	Outbound message interrupt status register
0x034	—	OMIMR	Outbound message interrupt mask register
0x040	—	IFQPR	Inbound FIFO queue port register
0x044	—	OFQPR	Outbound FIFO queue port register
—	0x0_0100	IMISR	Inbound message interrupt status register
—	0x0_0104	IMIMR	Inbound message interrupt mask register

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Table 9-7. I_2O Register Summary (Continued)

PCI Offset	Local Memory Offset	Acronym	Name
—	0x0_0120	IFHPR	Inbound free_FIFO head pointer register
—	0x0_0128	IFTPR	Inbound free_FIFO tail pointer register
—	0x0_0130	IPHPR	Inbound post_FIFO head pointer register
—	0x0_0138	IPTPR	Inbound post_FIFO tail pointer register
—	0x0_0140	OFHPR	Outbound free_FIFO head pointer register
—	0x0_0148	OFTPR	Outbound free_FIFO tail pointer register
—	0x0_0150	OPHPR	Outbound post_FIFO head pointer register
—	0x0_0158	OPTPR	Outbound post_FIFO tail pointer register
—	0x0_0164	MUCR	Messaging unit control register
—	0x0_0170	QBAR	Queue base address register. Must be set on 1-Mbyte boundary

9.3.3 FIFO Descriptions

There are two paths for messages—an inbound queue to receive messages from the remote host (and other IOPs) and an outbound queue to pass messages to a remote host. Each queue is implemented as a pair of FIFOs. The inbound and outbound message queues each consists of a free_list FIFO and a post_list FIFO.

Messages are comprised of frames that are at least 64 bytes long. The message frame address (MFA) points to the first byte of the message frame. The messages are located in a pool of system memory (any memory address accessible through the PCI bus). Tracking of the status and location of these messages is done with the four FIFOs that are located in local memory. One FIFO in each queue tracks the free MFAs (free_list FIFO). The other FIFO tracks the MFAs that have posted messages (post_list FIFO). These FIFOs are managed by the remote processors and the processor core through the MPC8240 I_2O registers. For more information, see Section 9.3.2, “I2O Register Summary”.

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Figure 9-4 shows an example of the message queues:

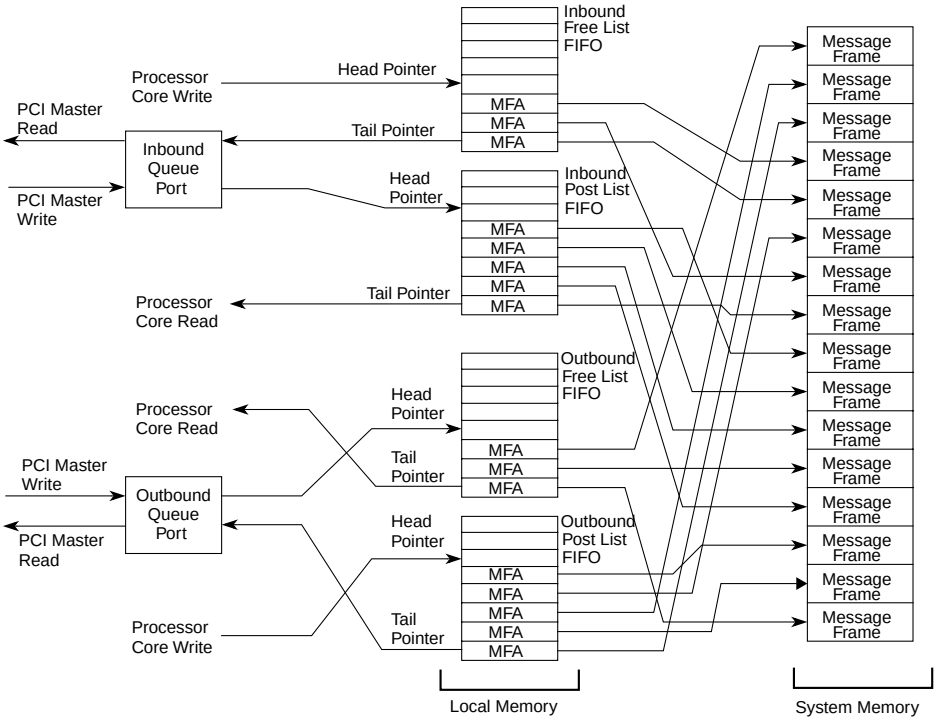

Figure 9-4. I_2O Message Queue Example

Table 9-8 lists the queue starting addresses for the FIFOs.

Table 9-8. Queue Starting Address

FIFO	Starting Address
Inbound free_list	QBA (specified in QBAR)
Inbound post_list	QBA + (1*FIFO size specified in MUCR)
Outbound post_list	QBA + (2*FIFO size specified in MUCR)
Outbound free_list	QBA + (3*FIFO size specified in MUCR)

The following subsections describe the inbound and outbound FIFOs of the I_2O interface.

9.3.3.1 Inbound FIFOs

The I_2O specification defines two inbound FIFOs—an inbound post_list FIFO and an inbound free_list FIFO. The inbound FIFOs allow external PCI masters to post messages to theMPC8240 processor core.

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9.3.3.1.1 Inbound Free_List FIFO

The inbound free_list FIFO holds the list of empty inbound MFAs. The external PCI master reads the inbound FIFO queue port register (IFQPR) which returns the MFA pointed to by the inbound free_FIFO tail pointer register (IFTPR). The MPC8240's I_2O unit then automatically increments the value in IFTPR.

If the inbound free_list FIFO is empty (no free MFA entries), the unit returns 0xFFFF_FFFF.

9.3.3.1.2 Inbound Post_List FIFO

The inbound post_list FIFO holds MFAs that are posted to the processor core from external PCI masters. PCI masters external to the MPC8240 write to the head of the FIFO by writing the MFA to the inbound FIFO queue port register (IFQPR). The I_2O unit transfers the MFA to the location pointed to by the inbound post_FIFO head pointer register (IPHPR).

After the MFA is written to the FIFO, the MPC8240's I_2O unit automatically increments the value in IPHPR to set up for the next message. In addition, an interrupt is generated to the processor core through the EPIC unit (provided the interrupt is not masked). The inbound post queue interrupt bit in the inbound message interrupt status register (IMISR[IPQI]) is set to indicate the condition. The processor core should clear the interrupt bit as part of the interrupt handler and read the message pointed to by the MFA located in the IPTPR. After the message has been read, the interrupt software must explicitly increment the value in IPTPR.

When the processor is done using the message, it must return the message to the inbound free_list FIFO.

9.3.3.2 Outbound FIFOs

The I_2O specification defines two outbound FIFOs—an outbound post_list FIFO and an outbound free_list FIFO. The outbound FIFOs are used to send messages from the processor core to a remote host processor.

9.3.3.2.1 Outbound Free_List FIFO

The outbound free_list FIFO holds the MFAs of the empty outbound message locations in local memory. When the processor core is ready to send an outbound message, it obtains MFA by reading the OFTPR; then it writes the message into the message frame. The OFTPR is managed by the processor core.

When an external PCI master is done using a message posted in the outbound post_list FIFO and needs to return the MFA to the free list, it writes to the outbound FIFO queue port register (OFQPR). The MPC8240 I_2O unit then automatically writes the MFA to the outbound free_FIFO head pointer register (OFHPR). This, in turn causes the value in OFHPR to be automatically incremented.

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9.3.3.2.2 Outbound Post_List FIFO

The outbound post_list FIFO holds MFAs that are posted from the processor core to remote processors. The processor core places messages in the outbound post_list FIFO by writing the MFA to OPHPR. This software must then increment the value in OPHPR.

When the FIFO is not empty (head and tail pointers are not equal), the outbound post_list queue interrupt bit in the outbound message interrupt status register (OMISR[OPQI]) is set. Additionally, the external MPC8240 PCI interrupt signal ($\overline{\text{INTA}}$) is asserted (if it is not masked). When the head and tail pointers are equal, OMISR[OPQI] is cleared. The outbound post_list queue interrupt can be masked using the outbound message interrupt mask register (OMIMR).

An external PCI master reads the outbound FIFO queue port register (OFQPR) to cause the MPC8240's I_2O unit to read the MFA from local memory pointed to by the OPTPR. The I_2O unit then automatically increments the value in OPTPR.

When the FIFO is empty (head and tail pointers are equal), the unit returns 0xFFFF_FFFF.

9.3.4 I_2O Register Descriptions

The following sections provide detailed descriptions of the I_2O registers and some of the bits that control the generic message and doorbell register interface in these registers. See Chapter 11, "Embedded Programmable Interrupt Controller (EPIC) Unit," for more information on the interrupt mechanisms of the MPC8240.

9.3.4.1 PCI-Accessible I_2O Registers

The OMISR, OMIMR, IFQPR, and OFQPR registers are used by PCI masters to access the MPC8240 I_2O unit. The processor core cannot access any of these registers.

9.3.4.1.1 Outbound Message Interrupt Status Register (OMISR)

The OMISR contains the interrupt status of the I_2O, doorbell register, and outbound message register events that cause the assertion of $\overline{\text{INTA}}$. These events are generated by blocks in the MPC8240 and the assertion of $\overline{\text{INTA}}$ signals an interrupt to the PCI bus on behalf of these blocks.

Writing a 1 to a set bit in OMISR clears the bit (except for read-only bits). Software attempting to determine the source of the interrupts should always perform a logical AND between the OMISR bits and their corresponding mask bits in the OMIMR.

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Figure 9-5 shows the bits of the OMISR.

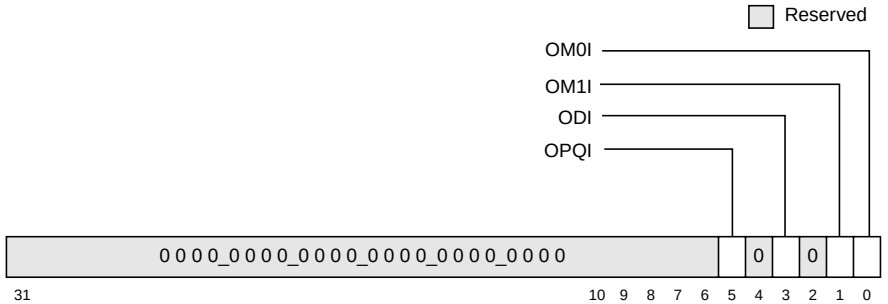

Figure 9-5. Outbound Message Interrupt Status Register (OMISR)

Table 9-9 shows the bit settings for the OMISR.

Table 9-9. OMISR Field Descriptions—Offset 0x030

Bits	Name	Reset Value	R/W	Description
31–6	—	All 0s	R	Reserved
5	OPQI	0	R	Outbound post queue interrupt (I_2O interface) 0 No messages in the outbound queue—To clear this bit, software has to read all the MFAs in the outbound post_list FIFO. 1 Indicates that a message or messages are posted to the outbound post_list FIFO through the OFQPR and $\overline{\text{INTA}}$ will be generated (if not masked). This bit is set independently of the outbound post queue interrupt mask (OMIMR[OPQIM]) bit.
4	—	0	R	Reserved
3	ODI	0	R	Outbound doorbell interrupt 0 No outbound doorbell interrupt—This bit is automatically cleared when all bits in the ODBR are cleared. 1 Indicates an outbound doorbell interrupt condition (a bit in ODBR is set). Set independently of the mask bit in OMIMR.
2	—	0	R	Reserved
1	OM1I	0	Read Write 1 clears this bit	Outbound message 1 interrupt 0 No outbound message 1 interrupt 1 Indicates an outbound message 1 interrupt condition (a write occurred to OMR1). Set independently of the mask bit in OMIMR.
0	OM0I	0	Read Write 1 clears this bit	Outbound message 0 interrupt 0 No outbound message 0 interrupt 1 Indicates an outbound message 0 interrupt condition (a write occurred to OMR0). Set independently of the mask bit in OMIMR.

9.3.4.1.2 Outbound Message Interrupt Mask Register (OMIMR)

The OMIMR contains the interrupt masks of the I_2O, doorbell register, and message register events generated by the MPC8240.

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Figure 9-6 shows the bits of the OMIMR.

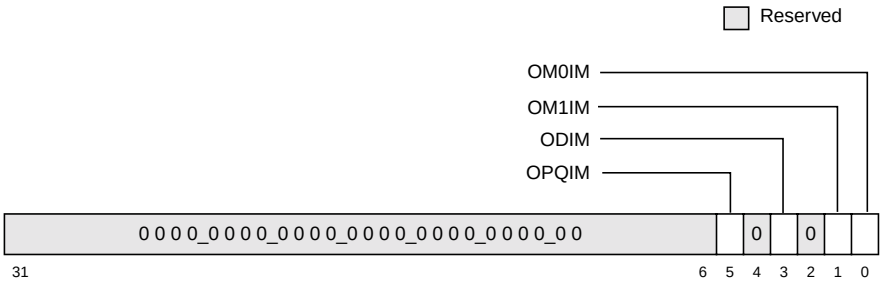

Figure 9-6. Outbound Message Interrupt Mask Register (OMIMR)

Table 9-10 shows the bit settings for the OMIMR.

Table 9-10. OMIMR Field Descriptions—Offset 0x034

Bits	Name	Reset Value	R/W	Description
31–6	—	All 0s	R	Reserved
5	OPQIM	0	R/W	Outbound post queue interrupt mask 0 Outbound post queue interrupt is allowed. 1 Outbound post queue interrupt is masked.
4	—	0	R	Reserved
3	ODIM	0	R/W	Outbound doorbell interrupt mask 0 Outbound doorbell interrupt is allowed. 1 Outbound doorbell interrupt is masked.
2	—	0	R	Reserved
1	OM1IM	0	R/W	Outbound message 1 interrupt mask 0 Outbound message 1 interrupt is allowed. 1 Outbound message 1 interrupt is masked.
0	OM0IM	0	R/W	Outbound message 0 interrupt mask 0 Outbound message 0 interrupt is allowed. 1 Outbound message 0 interrupt is masked.

9.3.4.1.3 Inbound FIFO Queue Port Register (IFQPR)

The IFQPR is used by PCI masters to access inbound messages in local memory. Figure 9-7 shows the bits of the IFQPR.

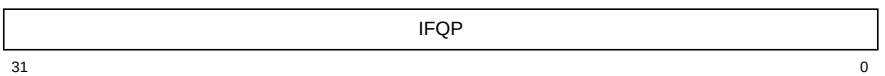

Figure 9-7. Inbound FIFO Queue Port Register (IFQPR)

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Table 9-11 shows the bit settings for the IFQPR.

Table 9-11. IFQPR Field Descriptions—Offset 0x040

Bits	Name	Reset Value	R/W	Description
31–0	IFQP	All 0s	R/W	Inbound FIFO queue port. Reading this register returns the MFA from the inbound free_list FIFO. Writing to this register posts the MFA to the inbound post_list FIFO.

9.3.4.1.4 Outbound FIFO Queue Port Register (OFQPR)

The OFQPR is used by PCI masters to access outbound messages in local memory. Figure 9-8 shows the bits of the OFQPR.

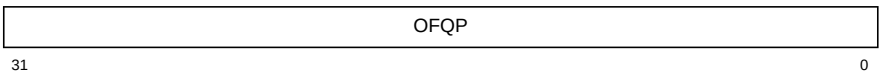

Figure 9-8. Outbound FIFO Queue Port Register (OFQPR)

Table 9-12 shows the bit settings for the OFQPR.

Table 9-12. OFQPR Field Descriptions—Offset 0x044

Bits	Name	Reset Value	R/W	Description
31–0	OFQP	All 0s	R/W	Outbound FIFO queue port. Reading this register returns the MFA from the outbound post_list FIFO. Writing to this register posts the MFA to the outbound free_list FIFO.

9.3.4.2 Processor-Accessible I_2O Registers

The following sections describe the I_2O registers accessible by the processor core and some of the bits that control the generic message and doorbell register interface in these registers.

9.3.4.2.1 Inbound Message Interrupt Status Register (IMISR)

The IMISR contains the interrupt status of the I_2O, doorbell register and message register events. These events are routed to the processor core from the MU with the internal $\overline{int}$ or $\overline{mcp}$ signals as described in Table 9-13. See Chapter 11, “Embedded Programmable Interrupt Controller (EPIC) Unit,” for more information about the assertion of $\overline{int}$ and Chapter 13, “Error Handling,” for more information about the enabling of machine check exceptions to the processor core.

Writing a 1 to a set bit in IMISR clears the bit (except for read-only bits). The processor core interrupt handling software must service these interrupts and clear these interrupt bits. Software attempting to determine the source of the interrupts should always perform a logical AND between the IMISR bits and their corresponding mask bits in the IMIMR. In the case of doorbell machine check or interrupt conditions, the corresponding read-only bits in IMISR (DMC and IDI) are cleared by writing a 0b1 to the corresponding machine check and interrupt bits in IDBR (causing them to be cleared).

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Figure 9-9 shows the bits of the IMISR.

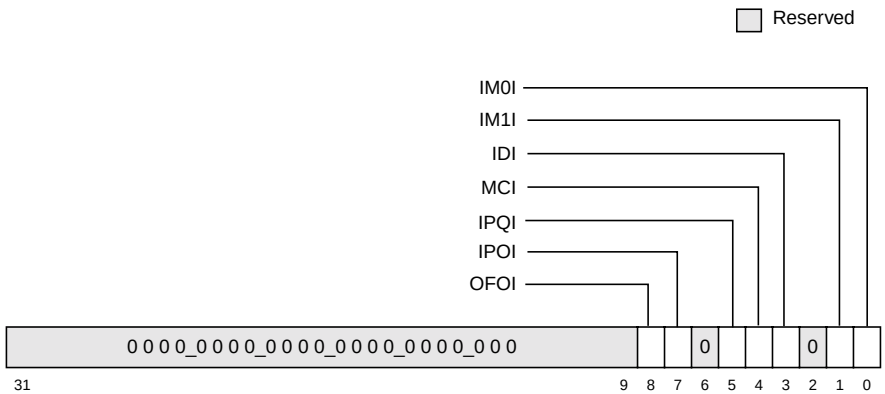

Figure 9-9. Inbound Message Interrupt Status Register (IMISR)

Table 9-13 shows the bit settings for the IMISR.

Table 9-13. IMISR Field Descriptions—Offset 0x0_0100

Bits	Name	Reset Value	R/W	Description
31–11	—	All 0s	R	Reserved
8	OFO	0	Read Write 1 clears this bit	Outbound free_list overflow condition 0 No overflow condition 1 Indicates that the outbound free_list FIFO head pointer is equal to the outbound free_list FIFO tail pointer and the queue is full. A machine check is signalled to the processor core through the internal mcp signal and a machine check exception is taken (if enabled). See Chapter 13, “Error Handling.” This bit is set only if the OFOM mask bit in IMIMR is cleared.
7	IPO	0	Read Write 1 clears this bit	Inbound post_list overflow condition 0 No overflow condition 1 Indicates that the inbound free_list FIFO head pointer is equal to the inbound free_list FIFO tail pointer and the queue is full. A machine check is signalled to the processor core through the internal mcp signal and a machine check exception is taken (if enabled). This bit is set only if the IPOM mask bit in IMIMR is cleared.
6	—	0	R	Reserved
5	IPQI	0	Read Write 1 clears this bit	Inbound post queue interrupt (I_2O interface) 0 No MFA in the IFQPR 1 Indicates that the PCI master has posted an MFA to the inbound post_list FIFO through the IFQPR. Interrupt is signalled to the processor core through the internal int signal. This bit is set only if the inbound post queue interrupt mask (IMIMR[IPQIM]) bit is cleared.
4	DMC	0	R	Doorbell register machine check condition 0 No doorbell register machine check condition.This bit is cleared when IDBR[MC] is cleared. 1 Indicates that a remote processor has generated a machine check condition (causing assertion of mcp) by setting IDBR[MC]. Note that this bit is set only if the mask bit, IMIMR[DMCM] = 0.

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Table 9-13. IMISR Field Descriptions—Offset 0x0_0100 (Continued)

Bits	Name	Reset Value	R/W	Description
3	IDI	0	R	Inbound doorbell interrupt 0 No inbound doorbell interrupt. This bit is cleared when the processor core clears IDBR[30–0]. 1 Indicates that at least one of IDBR[30–0] is set. Interrupt is signalled to the processor core through the internal $\overline{int}$ signal. This bit is set only if the mask bit (IDIM) in IMIMR is cleared.
2	—	0	R	Reserved
1	IM1I	0	Read; write 1 clears this bit	Inbound message 1 interrupt 0 No inbound message 1 interrupt. 1 Indicates an inbound message 1 interrupt condition (a write occurred to IMR1 from a remote PCI master). Interrupt is signalled to the processor core through the internal $\overline{int}$ signal. This bit is set only if the mask bit (IM1IM) in IMIMR is cleared.
0	IM0I	0	Read; write 1 clears this bit	Inbound message 0 interrupt 0 No inbound message 0 interrupt 1 Indicates an inbound message 0 interrupt condition (a write occurred to IMR0 from a remote PCI master). Interrupt is signalled to the processor core through the internal $\overline{int}$ signal. This bit is set only if the mask bit (IM0IM) in IMIMR is cleared.

9.3.4.2.2 Inbound Message Interrupt Mask Register (IMIMR)

The IMIMR contains the interrupt mask of the I_2O, doorbell register, and message register events generated by a remote PCI master. Figure 9-10 shows the bits of the IMIMR.

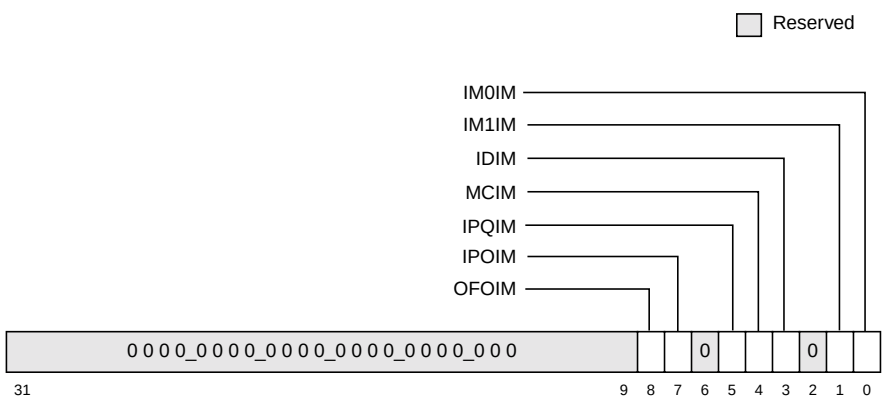

Figure 9-10. Inbound Message Interrupt Mask Register (IMIMR)

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Table 9-14 shows the bit settings for the IMIMR.

Table 9-14. IMIMR Field Descriptions—Offset 0x0_0104

Bits	Name	Reset Value	R/W	Description
31–9	—	All 0s	R	Reserved
8	OFOM	0	R/W	Outbound free_list overflow mask 0 Outbound free_list overflow is allowed (and causes assertion of $\overline{mcp}$). 1 Outbound free_list overflow is masked.
7	IPOM	0	R/W	Inbound post_list overflow mask 0 Inbound post_list overflow is allowed (and causes assertion of $\overline{mcp}$). 1 Inbound post_list overflow is masked.
6	—	0	R	Reserved
5	IPQIM	0	R/W	Inbound post queue interrupt mask 0 Inbound post queue interrupt is allowed. 1 Inbound post queue interrupt is masked.
4	DMCM	0	R/W	Doorbell register machine check mask 0 Doorbell machine check ($\overline{mcp}$) from IDBR[MC] is allowed. 1 Doorbell machine check ($\overline{mcp}$) from IDBR[MC] is masked. When this machine check condition is masked, the IMISR[DMC] is not set, regardless of the state of IDBR[MC].
3	IDIM	0	R/W	Inbound doorbell interrupt mask 0 Inbound doorbell interrupt is allowed. 1 Inbound doorbell interrupt is masked.
2	—	0	R	Reserved
1	IM1IM	0	R/W	Inbound message 1 interrupt 0 Inbound message 1 interrupt is allowed. 1 Inbound message 1 interrupt is masked.
0	IM0IM	0	R/W	Inbound message 0 interrupt 0 Inbound message 0 interrupt is allowed. 1 Inbound message 0 interrupt is masked.

9.3.4.2.3 Inbound Free_FIFO Head Pointer Register (IFHPR)

Free MFAs are posted by the processor core to the inbound free_list FIFO pointed to by the inbound free_FIFO head pointer register (IFHPR). The processor core is responsible for updating the contents of IFHPR. Figure 9-11 shows the bits of the IFHPR.

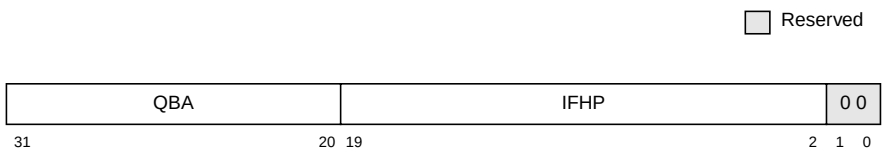

Figure 9-11. Inbound Free_FIFO Head Pointer Register (IFHPR)

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Table 9-15 shows the bit settings for the IFHPR.

Table 9-15. IFHPR Field Descriptions—Offset 0x0_0120

Bits	Name	Reset Value	R/W	Description
31–20	QBA	All 0s	R	Queue base address. When read, this field returns the contents of QBAR[31–20].
19–2	IFHP	All 0s	RW	Inbound free_FIFO head pointer. The processor maintains the local memory offset of the head pointer of the inbound free _list FIFO in this field.
1–0	—	00	R	Reserved

9.3.4.2.4 Inbound Free_FIFO Tail Pointer Register (IFTPR)

PCI masters pick up free MFAs from the inbound free_list FIFO pointed to by the inbound free_FIFO tail pointer register (IFTPR). The actual PCI reads of MFAs are performed through the inbound FIFO queue port register (IFQPR). The MPC8240 automatically increments the IFTP value after every read from IFQPR. Figure 9-12 shows the bits of the IFTPR.

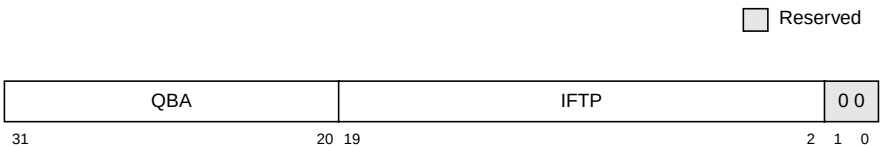

Figure 9-12. Inbound Free_FIFO Tail Pointer Register (IFTPR)

Table 9-16 shows the bit settings for the IFTPR.

Table 9-16. IFTPR Field Descriptions—Offset 0x0_0128

Bits	Name	Reset Value	R/W	Description
31–20	QBA	All 0s	R	Queue base address. When read, this field returns the contents of QBAR[31–20].
19–2	IFTP	All 0s	RW	Inbound free_FIFO tail pointer. Maintains the local memory offset of the tail pointer of the inbound free _list FIFO.
1–0	—	00	R	Reserved

9.3.4.2.5 Inbound Post_FIFO Head Pointer Register (IPHPR)

PCI masters post MFAs to the inbound post_list FIFO pointed to by the inbound post_FIFO head pointer register (IPHPR). The actual PCI writes are performed through the inbound FIFO queue port register (IFQPR). The MPC8240 automatically increments the IPHP value after every write to IFQPR. Figure 9-13 shows the bits of the IPHPR.

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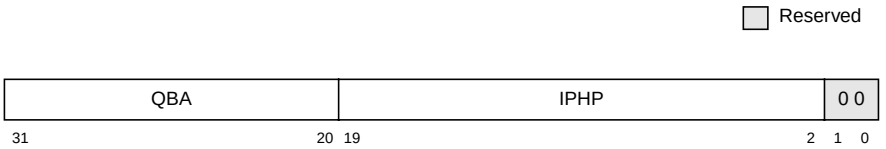

Figure 9-13. Inbound Post_FIFO Head Pointer Register (IPHPR)

Table 9-17 shows the bit settings for the IPHPR.

Table 9-17. IPHPR Field Descriptions—Offset 0x0_0130

Bits	Name	Reset Value	R/W	Description
31–20	QBA	All 0s	R	Queue base address. When read, this field returns the contents of QBAR[31–20].
19–2	IPHP	All 0s	RW	Inbound post_FIFO head pointer. Maintains the local memory offset of the head pointer of the inbound post _list FIFO.
1–0	—	00	R	Reserved

9.3.4.2.6 Inbound Post_FIFO Tail Pointer Register (IPTPR)

The processor picks up MFAs posted by PCI masters from the inbound post_list FIFO pointed to by the inbound post_FIFO tail pointer register (IPTPR). The processor core is responsible for updating the contents of IPTPR. Figure 9-14 shows the bits of the IPTPR.

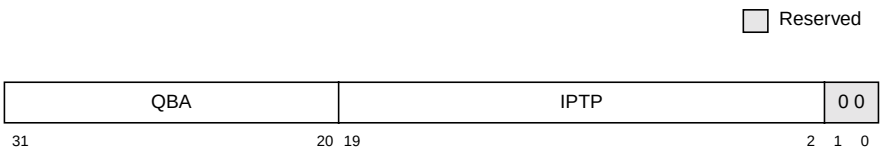

Figure 9-14. Inbound Post_FIFO Tail Pointer Register (IPTPR)

Table 9-18 shows the bit settings for the IPTPR.

Table 9-18. IPTPR Field Descriptions—Offset 0x0_0138

Bits	Name	Reset Value	R/W	Description
31–20	QBA	All 0s	R	Queue base address. When read, this field returns the contents of QBAR[31–20].
19–2	IPTP	All 0s	RW	Inbound post_FIFO tail pointer. The processor maintains the local memory offset of the inbound post_list FIFO tail pointer in this field.
1–0	—	00	R	Reserved

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9.3.4.2.7 Outbound Free_FIFO Head Pointer Register (OFHPR)

PCI masters return free MFAs to the inbound free_list FIFO pointed to by the inbound free_FIFO head pointer register (IFHPR). The actual PCI writes of MFAs are performed through the outbound FIFO queue port register (OFQPR). The MPC8240 automatically increments the OFTP value after every read from OFQPR. Figure 9-15 shows the bits of the OFHPR.

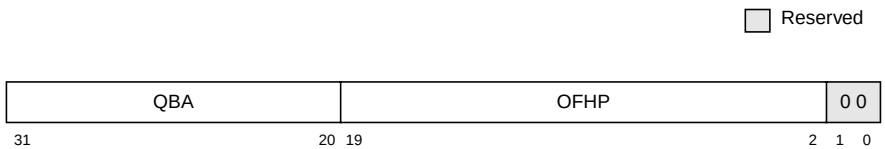

Figure 9-15. Outbound Free_FIFO Head Pointer Register (OFHPR)

Table 9-19 shows the bit settings for the OFHPR.

Table 9-19. OFHPR Field Descriptions—Offset 0x0_0140

Bits	Name	Reset Value	R/W	Description
31–20	QBA	All 0s	R	Queue base address. When read, this field returns the contents of QBAR[31–20].
19–2	OFHP	All 0s	RW	Outbound free_FIFO head pointer. Maintains the local memory offset of the head pointer of the outbound free_list FIFO.
1–0	—	0	R	Reserved

9.3.4.2.8 Outbound Free_FIFO Tail Pointer Register (OFTPR)

The processor picks up free MFAs from the outbound free_list FIFO pointed to by the outbound free_FIFO tail pointer register (OFTPR). The processor core is responsible for updating the contents of OFTPR. Figure 9-16 shows the bits of the OFTPR.

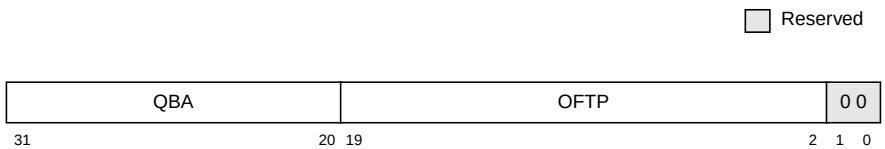

Figure 9-16. Outbound Free_FIFO Tail Pointer Register (OFTPR)

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Table 9-20 shows the bit settings for the OFTPR.

Table 9-20. OFTPR Field Descriptions—Offset 0x0_0148

Bits	Name	Reset Value	R/W	Description
31–20	QBA	All 0s	R	Queue base address. When read, this field returns the contents of QBAR[31–20].
19–2	OFTP	All 0s	RW	Outbound free_FIFO tail pointer. The processor maintains the local memory offset of the tail pointer of the outbound free_list FIFO in this field.
1–0	—	00	R	Reserved

9.3.4.2.9 Outbound Post_FIFO Head Pointer Register (OPHPR)

The processor core posts MFAs to the outbound post_list FIFO pointed to by the outbound post_FIFO head pointer register (OPHPR). The processor core is responsible for updating the contents of OPHPR. Figure 9-17 shows the bits of the OPHPR.

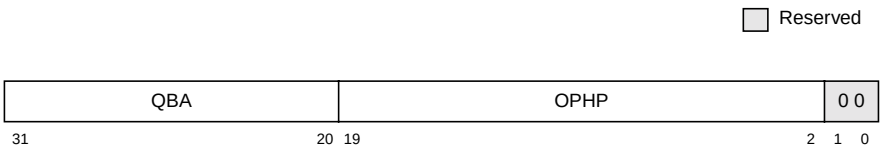

Figure 9-17. Outbound Post_FIFO Head Pointer Register (OPHPR)

Table 9-21 shows the bit settings for the OPHPR.

Table 9-21. OPHPR Field Descriptions—Offset 0x0_0150

Bits	Name	Reset Value	R/W	Description
31–20	QBA	All 0s	R	Queue base address. When read, this field returns the contents of QBAR[31–20].
19–2	OPHP	All 0s	RW	Outbound post_FIFO head pointer. The processor maintains the local memory offset of the head pointer of the outbound post_list FIFO in this field.
1–0	—	00	R	Reserved

9.3.4.2.10 Outbound Post_FIFO Tail Pointer Register (OPTPR)

PCI masters pick up posted MFAs from the outbound post_list FIFO pointed to by the outbound post_FIFO tail pointer register (OPTPR). The actual PCI reads of MFAs are performed through the outbound FIFO queue port register (OFQPR). The MPC8240 automatically increments the OPTP value after every read from OFQPR.

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Figure 9-18 shows the bits of the OPTPR.

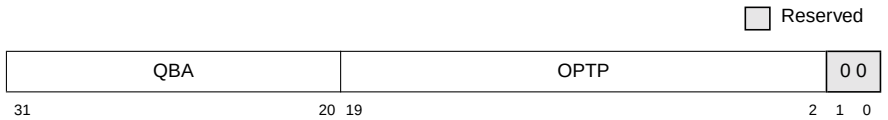

Figure 9-18. Outbound Post_FIFO Tail Pointer Register (OPTPR)

Table 9-22 shows the bit settings for the OPTPR.

Table 9-22. OPTPR Field Descriptions— Offset 0x0_0158

Bits	Name	Reset Value	R/W	Description
31–20	QBA	All 0s	R	Queue base address. When read, this field returns the contents of QBAR[31–20].
19–2	OPTP	All 0s	RW	Outbound post_FIFO tail pointer. Maintains the local memory offset of the tail pointer of the outbound post_list FIFO.
1–0	—	00	R	Reserved

9.3.4.2.11 Messaging Unit Control Register (MUCR)

The MUCR allows software to enable and set up the size of the inbound and outbound FIFOs. Figure 9-19 shows the bits of the MUCR.

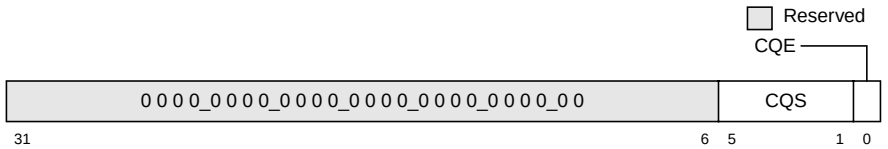

Figure 9-19. Messaging Unit Control Register (MUCR)

Table 9-23 shows the bit settings for the MUCR.

Table 9-23. MUCR Field Descriptions— Offset 0x0_0164

Bits	Name	Reset Value	R/W	Description
31–6	—	All 0s	R	Reserved
5–1	CQS	0b0_0001	RW	Circular queue size 0b0_0001: 4K entries (16 Kbytes) 0b0_0010: 8K entries (32 Kbytes) 0b0_0100: 16K entries (64 Kbytes) 0b0_1000: 32K entries (128 Kbytes) 0b1_0000: 64K entries (256 Kbytes)
0	CQE	0	RW	Circular queue enable 0 PCI writes to IFQPR and OFQPR are ignored and reads return 0xFFFF_FFFF. 1 Allows PCI masters to access the inbound and outbound queue ports (IFQPR and OFQPR). Usually, this bit is set only after software has initialized all pointers and configuration registers.

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9.3.4.2.12 Queue Base Address Register (QBAR)

The QBAR specifies the beginning address of the circular queue structure in local memory. Figure 9-20 shows the bits of the QBAR.

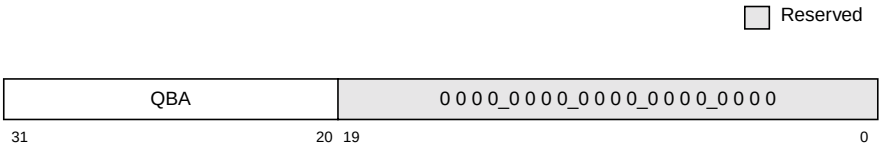

Figure 9-20. Queue Base Address Register (QBAR)

Table 9-24 shows the bit settings for the QBAR.

Table 9-24. QBAR Field Descriptions— Offset 0x0_0170

Bits	Name	Reset Value	R/W	Description
31–20	QBA	All 0s	RW	Queue base address. Base address of circular queue in local memory. Note that the circular queue must be aligned on a 1-Mbyte boundary.
19–0	—	All 0s	R	Reserved

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Chapter 10
I²C Interface

This chapter describes the I²C (inter-integrated circuit) interface on the MPC8240.

10.1 I²C Interface Overview

The I²C interface is a two-wire, bidirectional serial bus developed by Philips that provides a simple, efficient way to exchange data between integrated circuit (IC) devices. The I²C interface allows the MPC8240 to exchange data with other I²C devices such as microcontrollers, EEPROMs, real-time clock devices, A/D converters, and LCDs. The two-wire bus—serial data and serial clock—minimizes device interconnections. The synchronous, multimaster bus of the I²C allows the connection of additional devices to the bus for expansion and system development.

The I²C interface is a true multimaster bus that includes collision detection and arbitration that prevent data corruption if two or more masters attempt to control the bus simultaneously. This feature allows for complex applications with multiprocessor control.

10.1.1 I²C Unit Features

The I²C unit on the MPC8240 consists of a transmitter/receiver unit, a clocking unit, and a control unit. Some of the features of the I²C unit are as follows:

- Two-wire interface
- Multimaster support
- Master or slave I²C mode support
- Software-programmable for one of 64 different serial clock frequencies
- Software-selectable acknowledge bit
- Interrupt-driven, byte-to-byte data transfer
- Arbitration-lost interrupt with automatic mode switching from master to slave
- Calling address identification interrupt
- START and STOP condition generation/detection
- Repeated START condition generation
- Acknowledge bit generation/detection

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- Bus-busy detection
- Programmable on-chip digital filter rejecting electrical spikes on the bus
- Module reset through software

10.1.2 I²C Interface Signal Summary

The I²C interface uses the serial data (SDA) signal and serial clock (SCL) signal for data transfer. All devices connected to these two signals must have open-drain or open-collector outputs. A logical AND function is performed on both signals with external pull-up resistors. Note that the signal patterns driven on SDA represent address, data, or read/write information at different stages of the protocol.

Table 10-1 summarizes the two signals that comprise the I²C interface.

Table 10-1. I²C Interface Signal Description

Signal Name	Idle State	I/O	State Meaning
SCL (serial clock)	HIGH	I	When the MPC8240 is idle or acts as a slave, SCL defaults as an input. The unit uses SCL to synchronize incoming data on SDA. The bus is assumed to be busy when SCL is detected low.
		O	As a master, the MPC8240 drives SCL along with SDA when transmitting. As a slave, the MPC8240 drives SCL low for data pacing.
SDA (serial data)	HIGH	I	When the MPC8240 is idle or in a receiving mode, SDA defaults as an input. The unit receives data from other I²C devices on SDA. The bus is assumed to be busy when SDA is detected low.
		O	When writing as a master or slave, the MPC8240 drives data on SDA synchronous to SCL.

10.1.3 I²C Register Summary

There are five registers in the I²C unit that are used for the address, data, configuration, control, and status of the I²C interface. These registers are located in the embedded utilities memory block; see Section 3.4, “Embedded Utilities Memory Block (EUMB).” Table 10-2 summarizes the I²C registers. Complete descriptions of these registers are provided in Section 10.3, “I2C Register Descriptions.”

Table 10-2. I²C Register Summary

Local Memory Offset	Register Name
0x0_3000	I²C address register (I2CADR)
0x0_3004	I²C frequency divider register (I2CFDR)
0x0_3008	I²C control register (I2CCR)
0x0_300C	I²C status register (I2CSR)
0x0_3010	I²C data register (I2CDR)

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10.1.4 I²C Block Diagram

The reset state of the I²C interface is as a slave receiver. Thus, when not explicitly programmed to be a master or to respond to a slave transmitter address, the I²C unit always defaults to slave receiver operation. Figure 10-1 shows a block diagram of the I²C unit.

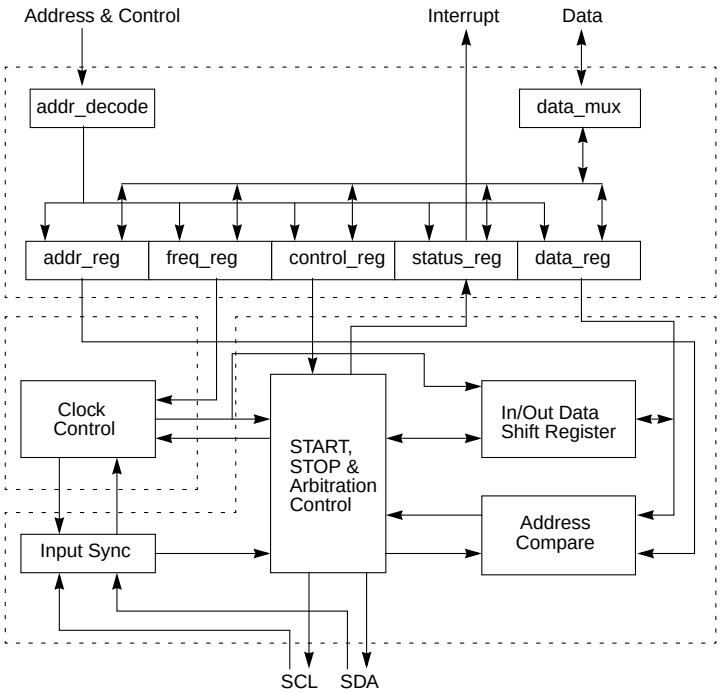

Figure 10-1. I²C Interface Block Diagram

10.2 I²C Protocol

A standard I²C transfer consists of four parts:

1. START condition
2. Slave target address transmission
3. Data transfer
4. STOP condition

Figure 10-2 shows the interaction of these four parts and the calling address, data byte, and new calling address components of the I²C protocol. The details of the protocol are described in the following subsections.

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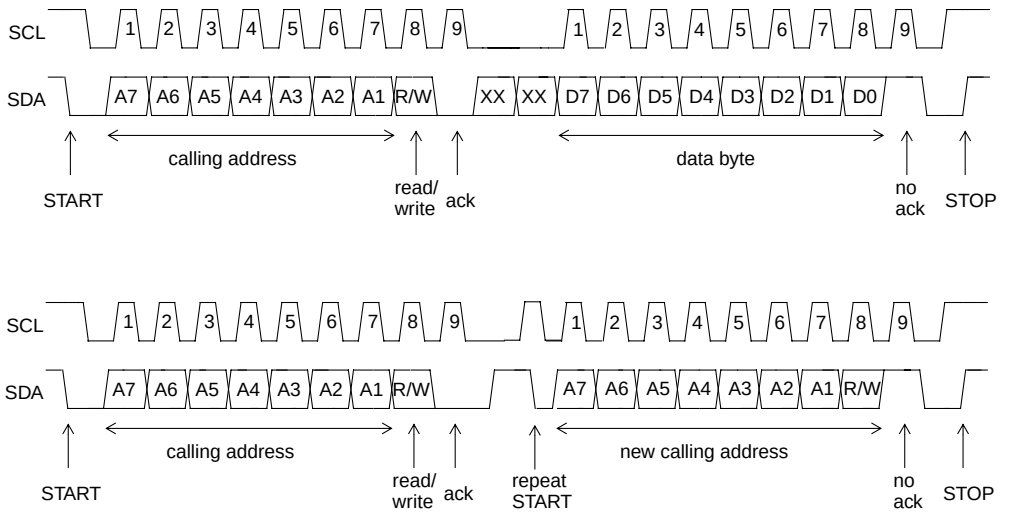

Figure 10-2. I²C Interface Transaction Protocol

10.2.1 START Condition

When no device is engaging the bus (both SDA and SCL lines are at logic high), a master can initiate a transfer by sending a START condition. As shown in Figure 10-2, a START condition is defined as a high-to-low transition of SDA while SCL is high. This condition denotes the beginning of a new data transfer (each data transfer can contain several bytes, and awakens all slaves.

10.2.2 Slave Address Transmission

The first byte of data transferred by the master immediately after the START condition is the slave address. This is a seven-bit calling address followed by a R/$\overline{W}$ bit, which indicates the direction of the data being transferred to the slave. No two slaves in the system can have the same address. In addition, when the I²C device is operating as a master, it must not transmit an address that is the same as its slave address. An I²C device cannot be master and slave at the same time.

The MPC8240 does not respond to a general call (broadcast) command unless the calling address matches its slave address. Because general call broadcasts an address of 0b0000_000, only MPC8240s with a slave address of 0b0000_000 would respond. When this occurs, the MPC8240 drives SDA low during the address acknowledge cycle.

Only the slave with a calling address that matches the one transmitted by the master responds by returning an acknowledge bit (pulling the SDA signal low at the 9th clock) as shown in Figure 10-2. If no slave acknowledges the address, the master should generate a STOP condition or a repeated START condition.

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10.2.3 Data Transfer

When successful slave addressing is achieved (and SCL returns to zero), the data transfer can proceed on a byte-to-byte basis in the direction specified by the R/$\overline{W}$ bit sent by the calling master.

Each data byte is eight bits long. Data bits can be changed only while the SCL signal is low and must be held stable while the SCL signal is high, as shown in Figure 10-2. There is one clock pulse on SCL for each data bit, and the most significant bit (msb) is transmitted first. Each byte of data must be followed by an acknowledge bit, which is signalled from the receiving device by pulling the SDA line low at the 9th clock. Therefore, one complete data byte transfer takes nine clock pulses. Several bytes can be transferred during a data transfer session.

If the slave receiver does not acknowledge the master, the SDA line must be left high by the slave. The master can then generate a stop condition to abort the data transfer or a START condition (repeated START) to begin a new calling.

If the master receiver does not acknowledge the slave transmitter after a byte of transmission, the slave interprets that the end-of-data has been reached. Then the slave releases the SDA line for the master to generate a STOP or a START condition.

10.2.4 Repeated START Condition

As shown in Figure 10-2, a repeated START condition is a START condition generated without a STOP condition to terminate the previous transfer. The master uses this method to communicate with another slave or with the same slave in a different mode (transmit/receive mode) without releasing the bus.

10.2.5 STOP Condition

The master can terminate the transfer by generating a STOP condition to free the bus. A STOP condition is defined as a low-to-high transition of the SDA signal while SCL is high. For more information, see Figure 10-2. Note that a master can generate a STOP even if the slave has transmitted an acknowledge bit, at which point the slave must release the bus.

As described in Section 10.2.4, “Repeated START Condition,” the master can generate a START condition followed by a calling address without generating a STOP condition for the previous transfer. This is called a repeated START condition.

10.2.6 Arbitration Procedure

The I2C interface is a true multiple master bus that allows more than one master device to be connected on it. If two or more masters try to control the bus simultaneously, each master (including the MPC8240) has a clock synchronization procedure that determines the bus clock—the low period is equal to the longest clock low period, and the high is equal to the

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shortest one among the masters. A bus master loses arbitration if it transmits a logic 1 on SDA while another master transmits a logic 0. The losing masters immediately switch over to slave-receive mode and stop driving the SDA line. In this case, the transition from master to slave mode does not generate a STOP condition. Meanwhile, the I^2C unit sets the I2CSR[MAL] status bit to indicate the loss of arbitration and, as a slave, services the transaction if it is directed to itself.

Arbitration is lost (and I2CSR[MAL] is set) in the following circumstances:

- SDA sampled as low when the master drives a high during address or data-transmit cycle.
- SDA sampled as low when the master drives a high during the acknowledge bit of a data-receive cycle.
- A START condition is attempted when the bus is busy.
- A repeated START condition is requested in slave mode.

Note that the MPC8240 does not automatically retry a failed transfer attempt.

If the I^2C module of the MPC8240 is enabled in the middle of an ongoing byte transfer, the interface behaves as follows:

- Slave mode—the MPC8240 ignores the current transfer on the bus and starts operating whenever a subsequent START condition is detected.
- Master mode—the MPC8240 will not be aware that the bus is busy; therefore, if a START condition is initiated, the current bus cycle can become corrupt. This ultimately results in the current bus master of the I^2C interface losing arbitration, after which bus operations return to normal.

10.2.7 Clock Synchronization

Due to the wire AND logic on the SCL line, a high-to-low transition on the SCL line affects all the devices connected on the bus. The devices begin counting their low period when the master drives the SCL line low. Once a device has driven SCL low, it holds the SCL line low until the clock high state is reached. However, the change of low-to-high in a device clock may not change the state of the SCL line if another device is still within its low period. Therefore, synchronized clock SCL is held low by the device with the longest low period. Devices with shorter low periods enter a high wait state during this time. When all devices concerned have counted off their low period, the synchronized SCL line is released and pulled high. Then there is no difference between the devices' clocks and the state of the SCL line, and all the devices begin counting their high periods. The first device to complete its high period pulls the SCL line low again.

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10.2.8 Handshaking

The clock synchronization mechanism can be used as a handshake in data transfer. Slave devices can hold the SCL low after completion of one byte transfer (9 bits). In such cases, it halts the bus clock and forces the master clock into wait states until the slave releases the SCL line.

10.2.9 Clock Stretching

Slaves can use the clock synchronization mechanism to slow down the transfer bit rate. After the master has driven the SCL line low, the slave can drive SCL low for the required period and then release it. If the slave SCL low period is greater than the master SCL low period, then the resulting SCL bus signal low period is stretched.

10.3 I2C Register Descriptions

This section describes the I2C registers in detail.

NOTE:

Even though reserved fields return 0, this should not be assumed by the programmer. Reserved bits should always be written with the value they returned when read. In other words, the register should be programmed by reading the value, modifying the appropriate fields, and writing back the value.

This does not apply to the I2C data register (I2CDR).

The I2C registers in this chapter are shown in little-endian format. If the system is big-endian, software must swap the bytes appropriately.

10.3.1 I2C Address Register (I2CADR)

The I2CADR, shown in Figure 10-3, contains the address that the I2C interface responds to when addressed as a slave. Note that it is not the address sent on the bus during the address calling cycle when the MPC8240 is in master mode.

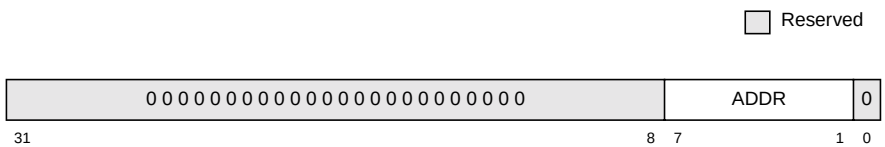

Figure 10-3. I2C Address Register (I2CADR)

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Table 10-3 describes the bit settings of I2CADR.

Table 10-3. I2CADR Field Descriptions—Offset 0x0_3000

Bits	Name	Reset Value	R/W	Description
31–8	—	All zeros	R	Reserved
7–1	ADDR	0x00	R/W	Slave address. Contains the specific address to which the MPC8240 responds as a slave on the I²C interface. Note that the default mode of the I²C interface is slave mode for an address match.
0	—	0	R	Reserved

10.3.2 I²C Frequency Divider Register (I2CFDR)

The I2CFDR, shown in Figure 10-4, configures the sampling rate and the clock bit rate for the I²C unit.

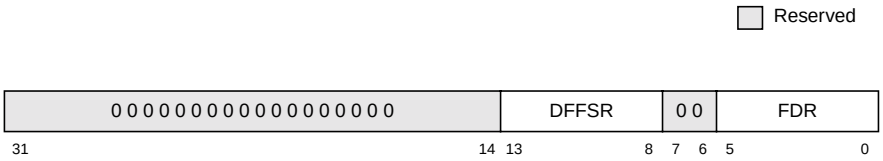

Figure 10-4. I²C Frequency Divider Register (I2CFDR)

Table 10-4 describes the bit settings of the I2CFDR.

Table 10-4. I2CFDR Field Descriptions—Offset 0x0_3004

Bits	Name	Reset Value	R/W	Description
31–14	—	All 0s	R	Reserved
13–8	DFFSR	0x10	R/W	Digital filter frequency sampling rate—To assist in filtering out signal noise, the sample rate is programmable; this field is used to prescale the frequency at which the digital filter takes samples from the I²C bus. The resulting sampling rate is the local memory frequency (SDRAM_CLK) divided by the non-zero value set in this field. If DFFSR is set to zero, the I²C bus sample points default to the reset divisor 0x10.
7–6	—	00	R	Reserved
5–0	FDR	0x00	R/W	Frequency divider ratio—Used to prescale the clock for bit rate selection. The serial bit clock frequency of SCL is equal to the local memory clock (SDRAM_CLK) divided by the divider shown in Table 10-5. Note that the frequency divider value can be changed at any point in a program.

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Table 10-5 maps the I2CFDR[FDR] field to the clock divider values.

Table 10-5. Serial Bit Clock Frequency Divider Selections

FDR	Divider (Decimal)	FDR	Divider (Decimal)
0x00	288	0x20	160
0x01	320	0x21	192
0x02	384	0x22	224
0x03	480	0x23	256
0x04	576	0x24	320
0x05	640	0x25	384
0x06	768	0x26	448
0x07	960	0x27	512
0x08	1152	0x28	640
0x09	1280	0x29	768
0x0A	1536	0x2A	896
0x0B	1920	0x2B	1024
0x0C	2304	0x2C	1280
0x0D	2560	0x2D	1536
0x0E	3072	0x2E	1792
0x0F	3840	0x2F	2048
0x10	4608	0x30	2560
0x11	5120	0x31	3072
0x12	6144	0x32	3584
0x13	7680	0x33	4096
0x14	9216	0x34	5120
0x15	10240	0x35	6144
0x16	12288	0x36	7168
0x17	15360	0x37	8192
0x18	18432	0x38	10240
0x19	20480	0x39	12288
0x1A	24576	0x3A	14336
0x1B	30720	0x3B	16384
0x1C	36864	0x3C	20480
0x1D	40960	0x3D	24576
0x1E	49152	0x3E	28672
0x1F	61440	0x3F	32768

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10.3.3 I²C Control Register (I2CCR)

The I2CCR controls the modes of the I²C interface, and is shown in Figure 10-5.

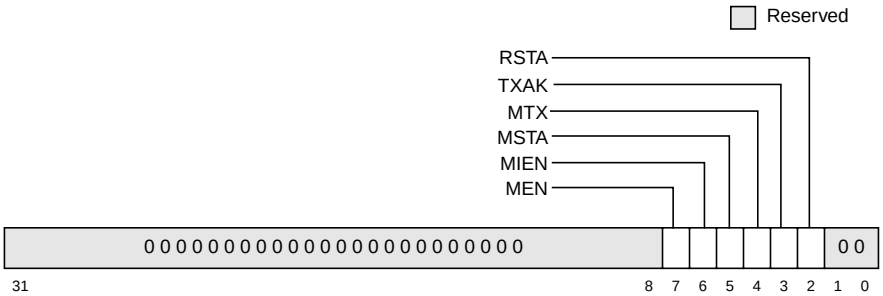

Figure 10-5. I²C Control Register (I2CCR)

Table 10-3 describes the bit settings of the I2CCR.

Table 10-6. I2CCR Field Descriptions—Offset 0x0_3008

Bits	Name	Reset Value	R/W	Description
31–8	—		R	Reserved
7	MEN	0	R/W	Module enable. This bit controls the software reset of the I²C module. 0 The module is reset and disabled. When low, the interface is held in reset. In this state, all the registers except I2CDR can still be accessed. 1 The I²C module is enabled. This bit must be set before any other control register bits have any effect. All I²C registers for slave receive or master START can be initialized before setting this bit. Refer to Section 10.2.6, “Arbitration Procedure.”
6	MIEN	0	R/W	Module interrupt enable 0 Interrupts from the I²C module are disabled. This does not clear any pending interrupt conditions. 1 Interrupts from the I²C module are enabled. When an interrupt condition occurs, an interrupt ($\overline{\text{int}}$) is generated, provided I2CSR[MIF] is also set.
5	MSTA	0	R/W	Master/slave mode START 0 Slave mode. When this bit is changed from a 1 to 0, a STOP condition is generated and the mode changes from master to slave. 1 Master mode. When this bit is changed from a 0 to 1, a START condition is generated on the bus, and the master mode is selected. The MSTA bit is cleared without generating a STOP condition when the master loses arbitration. See Section 10.2.6, “Arbitration Procedure.”
4	MTX	0	R/W	Transmit/receive mode select. This bit selects the direction of the master and slave transfers. When configured as a slave, this bit should be set by software according to I2CSR[SRW]. In master mode, the bit should be set according to the type of transfer required. Therefore, for address cycles, this bit will always be high. 0 Receive mode 1 Transmit mode The MTX bit is cleared when the master loses arbitration.

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Table 10-6. I2CCR Field Descriptions—Offset 0x0_3008 (Continued)

Bits	Name	Reset Value	R/W	Description
3	TXAK	0	R/W	Transfer acknowledge. This bit specifies the value driven onto the SDA line during acknowledge cycles for both master and slave receivers. The value of this bit applies only when the I2C module is configured as a receiver, not a transmitter and does not apply to address cycles; when the MPC8240 is addressed as a slave, an acknowledge is always sent. 0 An acknowledge signal (low value on SDA) is sent out to the bus at the 9th clock bit after receiving one byte of data. 1 No acknowledge signal response is sent (that is, acknowledge value on SDA is high).
2	RSTA	0	W	Repeat START. Setting this bit causes a repeated START condition to be always generated on the bus, provided the MPC8240 is the current bus master. Attempting a repeated START at the wrong time (or if the bus is owned by another master) results in loss of arbitration. Note that this bit is not readable. 0 No repeat START condition 1 Generates repeat START condition
1–0	—	00	R	Reserved

10.3.4 I2C Status Register (I2CSR)

The status register, shown in Figure 10-6, is read-only with the exception of the MIF and MAL bits, which can be cleared by software. The MCF and RXAK bits are set at reset; all other I2CSR bits are cleared on reset.

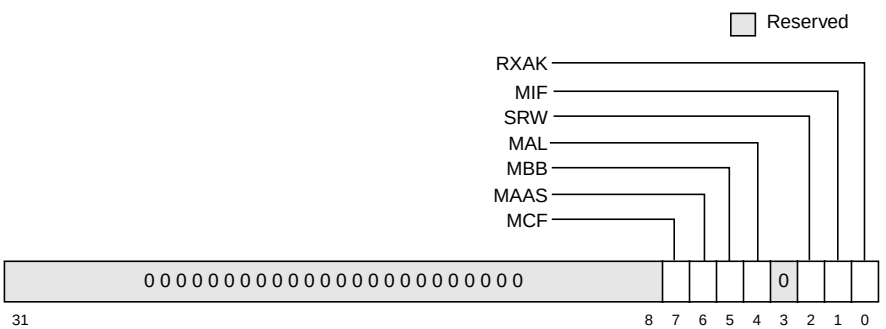

Figure 10-6. I2C Status Register (I2CSR)

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Table 10-7 describes the bits settings of the I2CSR.

Table 10-7. I2CSR Field Descriptions—Offset 0x0_300C

Bits	Name	Reset Value	R/W	Description
31–8	—	0	R	Reserved
7	MCF	1	R	Data transferring. While one byte of data is being transferred, this bit is cleared. It is set by the falling edge of the 9th clock of a byte transfer. 0 Transfer in progress. MCF is cleared when I2CDR is read in receive mode or when I2CDR is written in transmit mode. 1 Transfer complete
6	MAAS	0	R	Addressed as a slave. When the value in I2CADR matches the calling address, this bit is set. The processor is interrupted (by the $\overline{\text{int}}$ signal through EPIC), provided I2CCR[MIEN] is set. Next, the processor must check the SRW bit and set I2CCR[MTX] accordingly. Writing to the I2CCR automatically clears this bit. 0 Not addressed as a slave 1 Addressed as a slave
5	MBB	0	R	Bus busy. This bit indicates the status of the bus. When a START condition is detected, MBB is set. If a STOP condition is detected, it is cleared. 0 I^2C bus is idle. 1 I^2C bus is busy.
4	MAL	0	R/W	Arbitration lost. This bit is automatically set when the arbitration procedure is lost. Note that the MPC8240 does not automatically retry a failed transfer attempt. 0 Arbitration is not lost. Can only be cleared by software. 1 Arbitration is lost. See Section 10.2.6, “Arbitration Procedure.”
3	—	0	R	Reserved
2	SRW	0	R	Slave read/write. When MAAS is set, SRW indicates the value of the R/$\overline{\text{W}}$ command bit of the calling address sent from the master. 0 Slave receive, master writing to slave 1 Slave transmit, master reading from slave This bit is valid only when both of the following occur: • A complete transfer has occurred and no other transfers have been initiated, • The I^2C interface is configured as a slave and has an address match. By checking this bit, the processor can select slave transmit/receive mode according to the command of the master.
1	MIF	0	R/W	Module interrupt. The MIF bit is set when an interrupt is pending, causing a processor interrupt request (provided I2CCR[MIEN] is set). 0 No interrupt pending. Can only be cleared by software 1 Interrupt pending. MIF is set when one of the following events occurs: • One byte of data is transferred (set at the falling edge of the 9th clock) • The value in I2CADR matches the calling address in slave-receive mode • Arbitration is lost. See Section 10.2.6, “Arbitration Procedure.”
0	RXAK	1	R	Received acknowledge. The value of SDA during the acknowledge bit of a bus cycle. If the received acknowledge bit (RXAK) is low, it indicates that an acknowledge signal has been received after the completion of eight bits of data transmission on the bus. If RXAK is high, it means no acknowledge signal has been detected at the 9th clock. 0 Acknowledge received 1 No acknowledge received

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10.3.5 I²C Data Register (I2CDR)

The data register is shown in Figure 10-7.

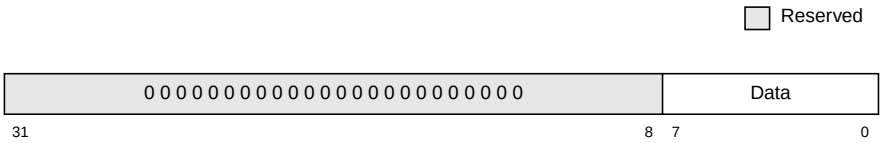

Figure 10-7. I²C Data Register (I2CDR)

Table 10-8 describes I2CDR.

Table 10-8. I2CDR Field Descriptions—Offset 0x0_3010

Bits	Name	Reset Value	R/W	Description
31–8	—		R	Reserved
7–0	DATA	0x00	R/W	Transmission starts when a 7-bit address is written to bits 7–1 of this field, the R/$\overline{W}$ bit (I2CCR[MTX]) is set, and the I²C interface is the master. A data transfer is initiated when data is written to the I2CDR. The most significant bit (msb) is sent first in both cases. In the master receive mode, reading the data register allows the read to occur but also initiates next byte data receiving. In slave mode, the same function is available after it is addressed.

10.4 Programming Guidelines

This section describes some programming guidelines recommended for the I²C interface on the MPC8240. Also included is a recommended flowchart for the I²C interrupt service routines.

The I²C registers in this chapter are shown in little-endian format. If the system is in big-endian mode, software must swap the bytes appropriately. Also, a **sync** assembly instruction should be executed after each I²C register read/write access to guarantee in-order execution.

The MPC8240 does not guarantee it will recover from all illegal I²C bus activity. In addition, a malfunctioning device may hold the bus captive. A good programming practice is for software to rely on a watchdog timer to help recover from I²C bus hangs. The recovery routine should also handle the case when the status bits returned after an interrupt are not consistent with what was expected due to illegal I²C bus protocol behavior.

Example I²C code can be found in the MPC8240 Device Driver Toolbox available through the PowerPC web site: www.mot.com/SPS/PowerPC/teksupport/faqsolutions/code (using the ‘code samples’ link for the Dink drivers directory).

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10.4.1 Initialization Sequence

A hard reset initializes all the I^2C registers to their default states. The following initialization sequence must be used before the I^2C unit:

1. If the processor's memory management unit (MMU) is enabled, all I^2C registers must be located in a cache-inhibited area.
2. Program the embedded utilities memory block; see Section 3.4, "Embedded Utilities Memory Block (EUMB)."
3. Update I2CFDR[FDR] and select the required division ratio to obtain the SCL frequency from the local memory clock (SDRAM_CLK).
4. Update the I2CADR to define the slave address for this device.
5. Modify I2CCR to select master/slave mode, transmit/receive mode, and interrupt-enable or disable.
6. Set the I2CCR[MEN] to enable the I^2C interface.

10.4.2 Generation of START

After initialization, the following sequence can be used to generate START:

1. If the MPC8240 is connected to a multimaster I^2C system, test the state of I2CSR[MBB] to check whether the serial bus is free (I2CSR[MBB] = 0) before switching to master mode.
2. Select master mode (set I2CCR[MSTA]) to transmit serial data.
3. Write the slave address being called into the data register (I2CDR). The data written to I2CDR[7–1] comprises the slave calling address. I2CCR[MTX] indicates the direction of transfer (transmit/receive) required from the slave.
4. Set I2CCR[MTX] for the address cycle.

The above scenario assumes the I^2C interrupt bit (I2CSR[MIF]) is cleared. If I2CSR[MIF] = 1 at any time, the I^2C interrupt handler should immediately handle the interrupt. See Section 10.4.8, "Interrupt Service Routine Flowchart."

10.4.3 Post-Transfer Software Response

Transmission or reception of a byte automatically sets the data transferring bit (I2CSR[MCF]), which indicates that one byte has been transferred. The I^2C interrupt bit (I2CSR[MIF]) is also set; an interrupt is generated to the processor if the interrupt function is enabled during the initialization sequence (I2CCR[MIEN] = 1). In the interrupt handler, software must do the following:

- Clear I2CSR[MIF]
- Read the contents of the I^2C data register (I2CDR) in receive mode or write to I2CDR in transmit mode. Note that this causes I2CSR[MCF] to be cleared. See Section 10.4.8, "Interrupt Service Routine Flowchart."

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When an interrupt occurs at the end of the address cycle, the master remains in transmit mode. If master receive mode is required, I2CCR[MTX] should be toggled at this stage. See Section 10.4.8, “Interrupt Service Routine Flowchart.”

If the interrupt function is disabled, software can service the I2CDR in the main program by monitoring I2CSR[MIF]. In this case, I2CSR[MIF] should be polled rather than I2CSR[MCF] because MCF behaves differently when arbitration is lost. Note that interrupt or other bus conditions may be detected by the MPC8240 before the I^2C signals have time to settle. Thus, when polling I2CSR[MIF] (or any other I2SCR bits), software delays may be needed (in order to give the I^2C signals sufficient time to settle).

During slave-mode address cycles (I2CSR[MAAS] = 1), I2CSR[SRW] should be read to determine the direction of the subsequent transfer and I2CCR[MTX] should be programmed accordingly. For slave-mode data cycles (I2CSR[MAAS] = 0), I2CSR[SRW] is not valid and I2CCR[MTX] should be read to determine the direction of the current transfer. See Section 10.4.8, “Interrupt Service Routine Flowchart,” for more details.

10.4.4 Generation of STOP

A data transfer ends with a STOP condition generated by the master device. A master transmitter can generate a STOP condition after all the data has been transmitted.

If a master receiver wants to terminate a data transfer, it must inform the slave transmitter by not acknowledging the last byte of data, which is done by setting the transmit acknowledge (I2CCR[TXAK]) bit before reading the next-to-last byte of data. For one-byte transfers, a dummy read should be performed by the interrupt service routine. (See Section 10.4.8, “Interrupt Service Routine Flowchart.”) Before the interrupt service routine reads the last byte of data, a STOP condition must first be generated by the MPC8240.

The MPC8240 automatically generates a STOP if I2CCR[TXAK] = 1. Therefore, I2CCR[TXAK] must be set to a 1 before allowing the MPC8240 to receive the last data byte on the I^2C bus.

10.4.5 Generation of Repeated START

At the end of a data transfer, if the master still wants to communicate on the bus, it can generate another START condition followed by another slave address without first generating a STOP condition by setting I2CCR[RSTA].

10.4.6 Generation of SCK when SDA Low

In some cases it is necessary to force the MPC8240 to become the I^2C bus master out of reset and drive the SCK signal (even though SDA may already be driven indicating that the bus is busy). This can occur when a system reset does not cause all I^2C devices to be reset. Thus, the SDA signal can be driven low by another I^2C device while the MPC8240 is coming out of reset and will stay low indefinitely. In order to force the MPC8240 to

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generate SCK so that the device driving SDA can finish its transaction, the following procedure can be used on the MPC8240:

1. Disable the I^2C and set the master bit by setting I2CCR to 0x20.
2. Enable the I^2C by setting I2CCR to 0xA0.
3. Read the I2CDR.
4. Return the MPC8240 to slave mode by setting I2CCR to 0x80.

10.4.7 Slave Mode Interrupt Service Routine

In the slave interrupt service routine, the module addressed as a slave should be tested to check if a calling of its own address has just been received. If I2CSR[MAAS] = 1, software should set the transmit/receive mode select bit (I2CCR[MTX]) according to the R/$\overline{W}$ command bit (I2CSR[SRW]). Writing to I2CCR clears I2CSR[MAAS] automatically. The only time I2CSR[MAAS] is read as set is from the interrupt handler at the end of that address cycle where an address match occurred; interrupts resulting from subsequent data transfers will have I2CSR[MAAS] = 0. A data transfer can then be initiated by writing to I2CDR for slave transmits or dummy reading from I2CDR in slave-receive mode. The slave drives SCL low between byte transfers. SCL is released when the I2CDR is accessed in the required mode.

10.4.7.1 Slave Transmitter and Received Acknowledge

In the slave transmitter routine, the received acknowledge bit (I2CSR[RXAK]) must be tested before sending the next byte of data. The master signals an end-of-data by not acknowledging the data transfer from the slave. When no acknowledge is received (I2CSR[RXAK] = 1), the slave transmitter interrupt routine must clear I2CCR[MTX] to switch the slave from transmitter to receiver mode. A dummy read of I2CDR then releases SCL so that the master can generate a STOP condition. See Section 10.4.8, “Interrupt Service Routine Flowchart.”

10.4.7.2 Loss of Arbitration and Forcing of Slave Mode

When a master loses arbitration (see Section 10.2.6, “Arbitration Procedure”), I2CSR[MAL] is set indicating loss of arbitration; I2CCR[MSTA] is cleared (changing the master to slave mode), and an interrupt occurs (if enabled) at the falling edge of the 9th clock of this transfer. Thus, the slave interrupt service routine should test I2CSR[MAL] first, and the software should clear I2CSR[MAL] if it is set.

10.4.8 Interrupt Service Routine Flowchart

Figure 10-8 shows an example algorithm for an I^2C interrupt service routine. Deviation from the flowchart may result in unpredictable I^2C bus behavior except that unlike what is shown in the flowchart, in slave receive mode, the interrupt service routine may need to set I2CCR[TXAK] when the next-to-last byte is to be accepted. It is recommended that a **sync** instruction follow each I^2C register read or write to guarantee in-order instruction execution.

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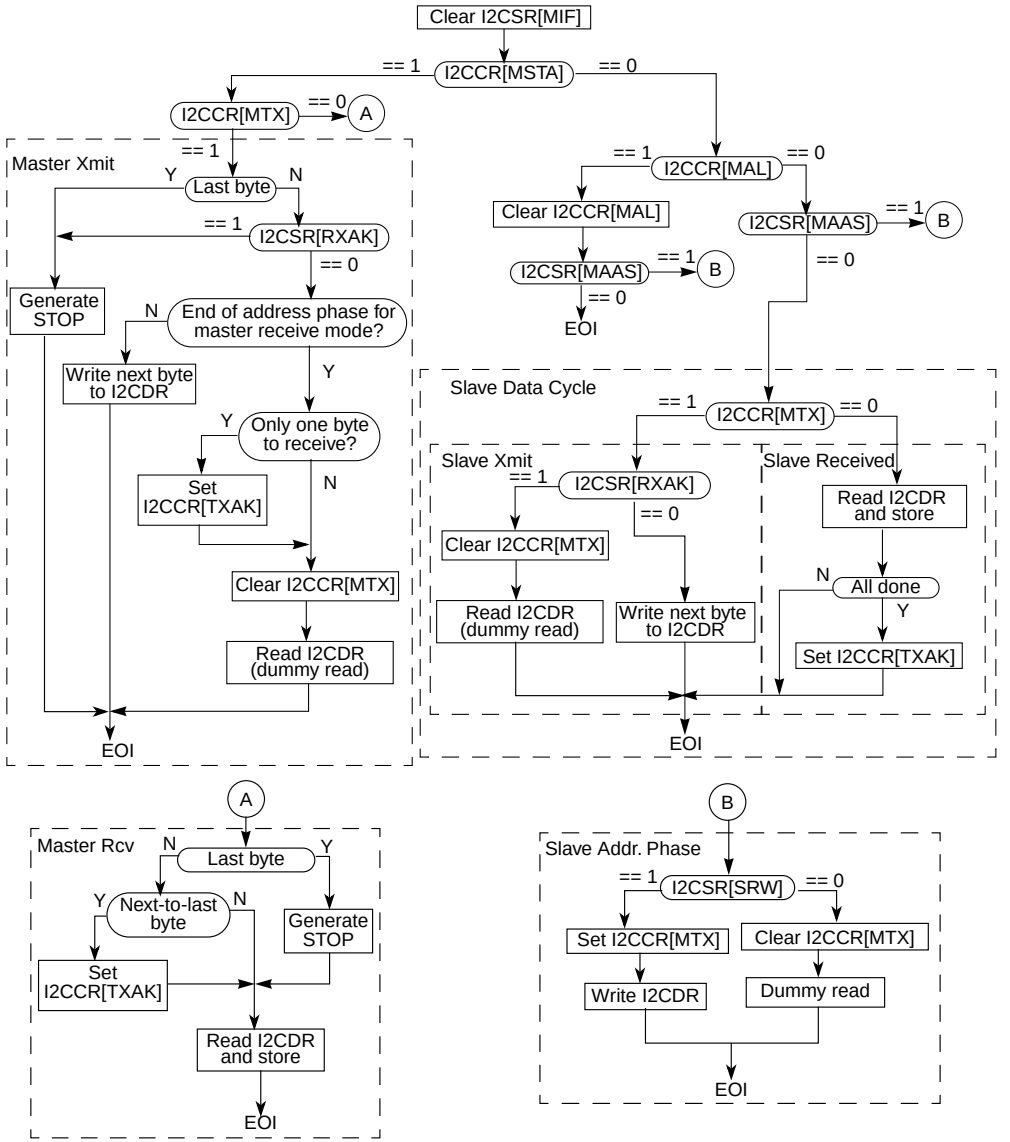

Figure 10-8. Example I²C Interrupt Service Routine Flowchart

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Chapter 11
Embedded Programmable Interrupt Controller (EPIC) Unit

This chapter describes the embedded programmable interrupt controller (EPIC) interrupt protocol, the various types of interrupt sources controlled by the EPIC unit, and a complete description of the EPIC registers with some programming guidelines.

The interrupt sources and soft reset controlled by the EPIC unit, the $\overline{sreset}$ signal, and the internal $\overline{mcp}$ generated by the MPC8240 central control unit (CCU) all cause exceptions in the processor core. The $\overline{int}$ signal is the main interrupt output from the EPIC to the processor core and causes the external interrupt exception. The external $\overline{\text{SRESET}}$ signal or the internal $\overline{sreset}$ output of the EPIC unit cause the soft reset processor exception. The machine check exception is caused by the internal $\overline{mcp}$ signal generated by the CCU, informing the processor of error conditions, the assertion of the external NMI signal, and other conditions. See Chapter 13, “Error Handling,” for further information on the sources of the internal $\overline{mcp}$ signal.

11.1 EPIC Unit Overview

The EPIC unit implements the necessary functions to provide a flexible and general-purpose interrupt controller solution. The EPIC pools hardware-generated interrupts from many sources, both within the MPC8240 and externally, and delivers them to the processor core in a prioritized manner. Note that the assertion of the $\overline{\text{INTA}}$ signal to the PCI bus is managed by the messaging unit (MU).

The EPIC solution adopts the OpenPIC architecture (architecture developed jointly by AMD and Cyrix for SMP interrupt solutions) and implements the logic and programming structures according to that specification. The MPC8240’s EPIC unit supports up to five external interrupts or one serial-style interrupt line (supporting 16 interrupts) and a pass-through mode. Additionally, the EPIC unit supports four internal logic-driven interrupts and four timers with interrupts. The following sections give an overview of the features of the EPIC unit and a complete summary of the signals used by the EPIC unit.

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11.1.1 EPIC Features Summary

The EPIC unit of the MPC8240 implements the following features:

- OpenPIC programming model
- Support for five external interrupt sources or one serial-style interrupt (16 interrupt sources)
- Four global, cascadable, high-resolution timers that can be interrupt sources
- Interrupt control for the MPC8240 I^2C unit, DMA unit (2 channels), and message unit (MU)
- Support for connection of external interrupt controller device such as an 8259 Programmable Interrupt Controller (PIC)
- In 8259 (pass-through) mode, it generates local (internal) interrupts output signal, $\overline{\text{L\_INT}}$.
- Processor initialization control—The processor can reset itself by setting the processor initialization register, causing the assertion of the internal $\overline{sreset}$ signal as described in Section 11.9.5, “Processor Initialization Register (PI).”
- Programmable resetting of the EPIC unit through the global configuration register
- 16 programmable interrupt priority levels
- Fully-nested interrupt delivery
- Spurious vector generation
- 32-bit configuration registers that are aligned on 128-bit boundaries

11.1.2 EPIC Interface Signal Description

In addition to the $\overline{int}$ signal, the external EPIC signals are defined in Table 11-1.

Table 11-1. EPIC Interface Signal Description

Signal Name	Pins	I/O	State Meaning
IRQ0/S_INT	1	I	Direct IRQ mode—Input representing an incoming interrupt request. Serial IRQ mode—Input representing the serial interrupt data stream. Note that the IRQ0 is used when operating in the pass-through mode.
IRQ1/S_CLK	1	I/O	Direct IRQ mode—Input representing an incoming interrupt request Serial IRQ mode—Output representing the serial clock by which the remote sequencer (interrupt source) clocks serial interrupts out.
IRQ2/S_RST	1	I/O	Direct IRQ mode—Input representing an incoming interrupt request Serial IRQ mode—Output pulse is active after EPIC resets and is set to serial mode. It determines the serial interrupt slot count for all external serial devices. Refer to Figure 11.7.

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Table 11-1. EPIC Interface Signal Description (Continued)

Signal Name	Pins	I/O	State Meaning
IRQ3/S_FRAME	1	I/O	Direct IRQ mode—Input representing an incoming interrupt request Serial IRQ mode—Output that pulses low each time the interrupt controller is sampling interrupt source 0.
IRQ4/L_INT	1	I/O	Direct IRQ mode—Input representing an incoming interrupt request Serial IRQ mode—Not used. Pass-through mode: output active low whenever there is an interrupt from MPC8240's internal dma0, dma1, MU, or I^2C units.

11.1.3 EPIC Block Diagram

The EPIC unit in the MPC8240 is accessible from the processor only. The processor reads and writes the configuration and status registers of EPIC. These registers are memory mapped.

The following block diagram shows the EPIC unit and its relationship to the processor core and external signals:

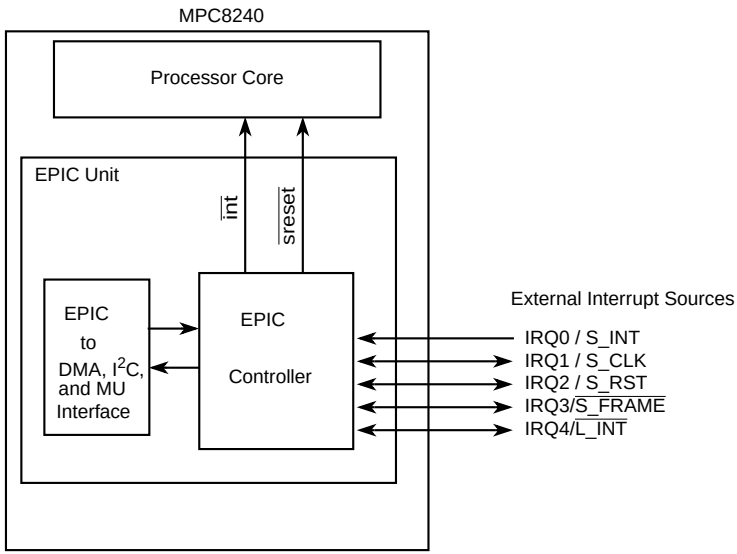

Figure 11-1. EPIC Unit Block Diagram

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11.2 EPIC Register Summary

The EPIC register map occupies a 256-Kbyte range of the embedded utilities memory block (EUMB). For further details, see Section 3.4, “Embedded Utilities Memory Block (EUMB).” If an access is attempted to an undefined portion of the map, the device returns 0x0000_0000 as its value on reads and does nothing on writes.

All EPIC registers are 32 bits wide and reside on 128-bit address boundaries. All addresses mentioned in this chapter are offsets from the EUMBBAR located at 0x78; see Section 4.5, “Embedded Utilities Memory Block Base Address Register—0x78.”

The EPIC address offset map is divided into the following four distinct areas:

- 0xnnn4_1000 – 0xnnn4_01F0—Global EPIC register map
- 0xnnn4_1100 – 0xnnn5_01F0—Global timer register map
- 0xnnn5_0200 – 0xnnn5_FFF0—Interrupt source configuration register map
- 0xnnn6_0000 – 0xnnn6_3FF0—Processor-related register map

Table 11-2 defines the address map for the global EPIC and timer registers. See Section 11.9, “Register Definitions,” for detailed register and field descriptions.

Table 11-2. EPIC Register Address Map—Global and Timer Registers

Address Offset from EUMBBAR	Register Name	Field Mnemonics
0x4_1000	Feature reporting register (FRR)	NIRQ, NCPU, VID
0x4_1010	Reserved	—
0x4_1020	Global configuration register (GCR)	R (reset), M (mode)
0x4_1030	EPIC interrupt configuration register (EICR)	R (clock ratio), SIE
0x4_1040–0x4_1070	Reserved	—
0x4_1080	EPIC vendor identification register (EVI)	STEP, DEVICE_ID, VENDOR_ID
0x4_1090	Processor initialization register (PI)	P0
0x4_10A0–0x4_10D0	Reserved	—
0x4_10E0	Spurious vector register (SVR)	VECTOR
0x4_10F0	Timer frequency reporting register (TFRR)	TIMER_FREQ
0x4_1100	Global timer 0 current count register (GTCCR0)	T (toggle), COUNT
0x4_1110	Global timer 0 base count register (GTBCR0)	CI, BASE_COUNT
0x4_1120	Global timer 0 vector/priority register (GTVPR0)	M, A, PRIORITY, VECTOR
0x4_1130	Global timer 0 destination register (GTDR0)	P0
0x4_1140	Global timer 1 current count register (GTCCR1)	T (toggle), COUNT
0x4_1150	Global timer 1 base count register (GTBCR1)	CI, BASE_COUNT
0x4_1160	Global timer 1 vector/priority register (GTVPR1)	M, A, PRIORITY, VECTOR

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Table 11-2. EPIC Register Address Map—Global and Timer Registers (Continued)

Address Offset from EUMBBAR	Register Name	Field Mnemonics
0x4_1170	Global timer 1 destination register (GTDR1)	P0
0x4_1180	Global timer 2 current count register (GTCCR2)	T (toggle), COUNT
0x4_1190	Global timer 2 base count register (GTBCR2)	CI, BASE_COUNT
0x4_11A0	Global timer 2 vector/priority register (GTVPR2)	M, A, PRIORITY, VECTOR
0x4_11B0	Global timer 2 destination register (GTDR2)	P0
0x4_11C0	Global timer 3 current count register (GTCCR3)	T (toggle), COUNT
0x4_11D0	Global timer 3 base count register (GTBCR3)	CI, BASE_COUNT
0x4_11E0	Global timer 3 vector/priority register (GTVPR3)	M, A, PRIORITY, VECTOR
0x4_11F0	Global timer 3 destination register (GTDR3)	P0
0x4_1200–0x5_01F0	Reserved	—

Table 11-3 defines the address map for the interrupt source configuration registers. Note that the address space 0x5_0200 through 0x5_0290 maps to the direct interrupt registers or the serial interrupt registers, depending on the setting of EICR[SIE].

Table 11-3. EPIC Register Address Map—Interrupt Source Configuration Registers

Address Offset from EUMBBAR	Register Name	Field Mnemonics
0x5_0200	IRQ0 vector/priority register (IVPR0)	M, A, P, S, PRIORITY, VECTOR
0x5_0210	IRQ0 destination register (IDR0)	P0
0x5_0220	IRQ1 vector/priority register (IVPR1)	M, A, P, S, PRIORITY, VECTOR
0x5_0230	IRQ1 destination (IDR1)	P0
0x5_0240	IRQ2 vector/priority register (IVPR2)	M, A, P, S, PRIORITY, VECTOR
0x5_0250	IRQ2 destination (IDR2)	P0
0x5_0260	IRQ3 vector/priority register (IVPR3)	M, A, P, S, PRIORITY, VECTOR
0x5_0270	IRQ3 destination (IDR3)	P0
0x5_0280	IRQ4 vector/priority register (IVPR4)	M, A, P, S, PRIORITY, VECTOR
0x5_0290	IRQ4 destination (IDR4)	P0
0x5_0200	Serial interrupt 0 vector/priority register (SVPR0)	M, A, P, S, PRIORITY, VECTOR
0x5_0210	Serial interrupt 0 destination register (SDR0)	P0
0x5_0220	Serial interrupt 1 vector/priority register (SVPR1)	M, A, P, S, PRIORITY, VECTOR
0x5_0230	Serial interrupt 1 destination register (SDR1)	P0
0x5_0240	Serial interrupt 2 vector/priority register (SVPR2)	M, A, P, S, PRIORITY, VECTOR
0x5_0250	Serial interrupt 2 destination register (SDR2)	P0
0x5_0260	Serial interrupt 3 vector/priority register (SVPR3)	M, A, P, S, PRIORITY, VECTOR

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Table 11-3. EPIC Register Address Map—Interrupt Source Configuration Registers (Continued)

Address Offset from EUMBBAR	Register Name	Field Mnemonics
0x5_0270	Serial interrupt 3 destination register (SDR3)	P0
0x5_0280	Serial interrupt 4 vector/priority register (SVPR4)	M, A, P, S, PRIORITY, VECTOR
0x5_0290	Serial interrupt 4 destination register (SDR4)	P0
0x5_02A0	Serial interrupt 5 vector/priority register (SVPR5)	M, A, P, S, PRIORITY, VECTOR
0x5_02B0	Serial interrupt 5 destination register (SDR5)	P0
0x5_02C0	Serial interrupt 6 vector/priority register (SVPR6)	M, A, P, S, PRIORITY, VECTOR
0x5_02D0	Serial interrupt 6 destination register (SDR6)	P0
0x5_02E0	Serial interrupt 7 vector/priority register (SVPR7)	M, A, P, S, PRIORITY, VECTOR
0x5_02F0	Serial interrupt 7 destination register (SDR7)	P0
0x5_0300	Serial interrupt 8 vector/priority register (SVPR8)	M, A, P, S, PRIORITY, VECTOR
0x5_0310	Serial interrupt 8 destination register (SDR8)	P0
0x5_0320	Serial interrupt 9 vector/priority register (SVPR9)	M, A, P, S, PRIORITY, VECTOR
0x5_0330	Serial interrupt 9 destination register (SDR9)	P0
0x5_0340	Serial interrupt 10 vector/priority register (SVPR10)	M, A, P, S, PRIORITY, VECTOR
0x5_0350	Serial interrupt 10 destination register (SDR10)	P0
0x5_0360	Serial interrupt 11 vector/priority register (SVPR11)	M, A, P, S, PRIORITY, VECTOR
0x5_0370	Serial interrupt 11 destination register (SDR11)	P0
0x5_0380	Serial interrupt 12 vector/priority register (SVPR12)	M, A, P, S, PRIORITY, VECTOR
0x5_0390	Serial interrupt 12 destination register (SDR12)	P0
0x5_03A0	Serial interrupt 13 vector/priority register (SVPR13)	M, A, P, S, PRIORITY, VECTOR
0x5_03B0	Serial interrupt 13 destination register (SDR13)	P0
0x5_03C0	Serial interrupt 14 vector/priority register (SVPR14)	M, A, P, S, PRIORITY, VECTOR
0x5_03D0	Serial interrupt 14 destination register (SDR14)	P0
0x5_03E0	Serial interrupt 15 vector/priority register (SVPR15)	M, A, P, S, PRIORITY, VECTOR
0x5_03F0	Serial interrupt 15 destination register (SDR15)	P0
0x5_0400–0x5_1010	Reserved	—
0x5_1020	I^2C interrupt vector/priority register (IIVPR0)	M, A, PRIORITY, VECTOR
0x5_1030	I^2C interrupt destination register (IIDR0)	P0
0x5_1040	DMA Ch0 interrupt vector/priority register (IIVPR1)	M, A, PRIORITY, VECTOR
0x5_1050	DMA Ch0 interrupt destination register (IIDR1)	P0
0x5_1060	DMA Ch1 interrupt vector/priority register (IIVPR2)	M, A, PRIORITY, VECTOR
0x5_1070	DMA Ch1 interrupt destination register (IIDR2)	P0
0x5_1080–0x5_10B0	Reserved	—
0x5_10C0	Message unit interrupt vector/priority register (IIVPR3)	M, A, PRIORITY, VECTOR

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Table 11-3. EPIC Register Address Map—Interrupt Source Configuration Registers (Continued)

Address Offset from EUMBBAR	Register Name	Field Mnemonics
0x5_10D0	Message unit interrupt destination register (IIDR3)	P0
0x5_10E0–0x5_FFF0	Reserved	—

Table 11-4. EPIC Register Address Map—Processor-Related Registers

Address Offset from EUMBBAR	Register Name	Field Mnemonics
0x6_0000–0x6_0070	Reserved	—
0x6_0080	Processor current task priority register (PCTPR)	TASKP
0x6_0090	Reserved	—
0x6_00A0	Processor interrupt acknowledge register (IACK)	VECTOR
0x6_00B0	Processor end-of-interrupt register (EOI)	EOI_CODE
0x6_00C0–0x6_3FF0	Reserved	—

11.3 EPIC Unit Interrupt Protocol

The following sections describe the priority of interrupts controlled by the EPIC unit, the interrupt acknowledge mechanism, the nesting of multiple interrupts, and the handling of spurious interrupts.

11.3.1 Interrupt Source Priority

The software assigns a priority value to each interrupt source by writing to the vector/priority register for the particular source. Priority values are in the range 0 to 15 of which 15 is the highest. In order for an interrupt to be signalled to the processor, the priority of the source must be greater than that of the current task priority of the processor (and the in-service interrupt source priority). Therefore, setting a source priority to zero inhibits that interrupt.

The EPIC unit services simultaneous interrupts occurring with the same priority according to the following set order: timer 0–timer 3, DMA 0, DMA 1, MU, I^2C, direct interrupts from IRQ[0:4] (or serial interrupt source).

11.3.2 Processor Current Task Priority

The EPIC unit has a processor current task priority register (PCTPR) set by system software to indicate the relative importance of the task running on the processor. When an interrupt has a priority level greater than the current task priority (and the in-service interrupt source priority), it is signalled to the processor. Therefore, setting the task priority to 15 in the PCTPR prevents the signalling of any interrupt to the processor.

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11.3.3 Interrupt Acknowledge

The EPIC unit notifies the processor core of an interrupt by asserting the $\overline{int}$ signal. When the processor acknowledges the interrupt request by reading the interrupt acknowledge register (IACK) in the EPIC unit, the EPIC returns the 8-bit interrupt vector associated with the interrupt source to the processor through the internal data bus. The interrupt is then considered to be in service, and it remains in service until the processor performs a write to the EPIC unit end of interrupt (EOI) register. Writing to the EOI register is referred to as an EOI cycle.

11.3.4 Nesting of Interrupts

If the processor core is servicing an interrupt, it can only be interrupted again if the EPIC unit receives an interrupt request from an interrupt source with a priority level greater than the current task priority (and the in-service interrupt source priority) and if MSR[EE] = 1.

Thus, although several interrupts may be simultaneously in service in the processor, the code currently executing is always handling the highest priority interrupt of all the interrupts in service. When the processor performs an EOI cycle, this highest priority interrupt is taken out of service. The next EOI cycle takes the next highest priority interrupt out of service, and so forth.

11.3.5 Spurious Vector Generation

Under certain circumstances, the EPIC may not have a valid vector to return to the processor during an interrupt acknowledge cycle (for example, if there is not a pending interrupt with a sufficient priority level). In these cases, the spurious vector from the spurious vector register is returned. The following cases cause a spurious vector fetch:

- $\overline{int}$ is asserted in response to an externally sourced interrupt which is activated with level sensitive logic, and the asserted level is negated before the interrupt is acknowledged.
- $\overline{int}$ is asserted for an interrupt source that is later masked by the setting of the mask bit in the vector/priority register before the interrupt is acknowledged.
- $\overline{int}$ is asserted for an interrupt source that is later masked by an increase in the task priority level before the interrupt is acknowledged.
- $\overline{int}$ is not asserted (that is, a programming error causes software to read the IACK with no interrupt pending).
- $\overline{int}$ is asserted when there is an illegal clock ratio value in the EPIC interrupt configuration register.

When there is a spurious interrupt, the interrupt handler should not write to the EOI register. Otherwise, a previously accepted interrupt might be cleared unintentionally.

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11.3.6 Internal Block Diagram Description

The internal block diagram shown in Figure 11-2 shows the interaction of the non-programmable EPIC registers and the interrupt delivery logic (assertion of the *int* signal to the processor).

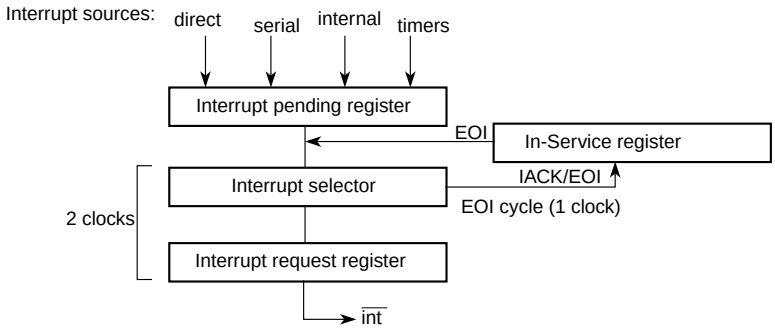

Figure 11-2. EPIC Interrupt Generation Block Diagram—Non-programmable Registers

11.3.6.1 Interrupt Pending Register (IPR)—Non-programmable

The interrupt signals in the EPIC unit are qualified and synchronized by the internal IPR, which has one bit for each interrupt. The mask bits from the appropriate vector/priority register are used to qualify the output of the IPR. Therefore, if an interrupt condition is detected when the mask bit is set, that interrupt is requested when the mask bit is cleared.

The interrupt sources are internal (I^2C, DMA or MU); EPIC (four timers); and external IRQ[0:4] (direct) or 16 serial interrupts. When there is a direct or serial interrupt and the sense bit = 0 (edge-sensitive), the interrupt acknowledge cycle causes the corresponding bit in the IPR to be cleared. When the sense bit = 1 (level-activated), the corresponding IPR bit is not cleared until the source signal is negated.

Because an edge-sensitive interrupt is not cleared until it is acknowledged and the default polarity/sense bits for all interrupts are set to edge-sensitive at power-up, it is possible for the EPIC unit to store detections of edges as pending interrupts. If software permanently sets the polarity/sense of an interrupt source to edge-sensitive and clears its mask bit, it can receive the vector for the interrupt source and not a spurious interrupt. To prevent having to handle a false interrupt, see the programming note in Section 11.8, “Programming Guidelines.”

11.3.6.2 Interrupt Selector (IS)

The interrupt selector (IS) receives interrupt requests from the IPR. The output of the IS is the highest priority interrupt that has been qualified. This output contains the priority of the selected interrupt and its source identification. The IS resolves an interrupt request in two clocks.

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During an EOI cycle, the value in the in-service register (ISR) is used to select which bits are to be cleared in the ISR. One cycle after an EOI cycle, the output of the IS contains the interrupt source identification and priority value to be cleared from the ISR. This interrupt source is the one with highest priority in the in-service register.

11.3.6.3 Interrupt Request Register (IRR)

The interrupt request register (IRR) always passes the output of the IS except during interrupt acknowledge cycles. During interrupt acknowledge cycles, interrupts in the IS and IPR are not propagated to guarantee that the vector that is read from the interrupt acknowledge register is not changing due to the arrival of a higher priority interrupt. The IRR also serves as a pipeline register for the two-clock propagation time through the IS.

11.3.6.4 In-Service Register (ISR)

The contents of the in-service register (ISR) are the priority and source values of the interrupts that are currently in service in the processor. The ISR receives an internal bit-set command during interrupt acknowledge cycles and an internal bit-clear command during EOI cycles.

11.4 EPIC Pass-Through Mode

The EPIC unit provides a mechanism to support alternate external interrupt controllers such as the PC-AT-compatible 8259 interrupt controller. After a hard reset, the EPIC unit defaults to pass-through mode. In this mode, interrupts from external source IRQ0 are passed directly to the processor; thus, the interrupt signal from the external interrupt controller can be connected to IRQ0 to cause direct interrupts to the processor. Note that IRQ0/S_INT is an active-high signal. Note also that the EPIC unit does not automatically perform a vector fetch from an 8259 interrupt controller.

When pass-through mode is enabled, none of the internally generated interrupts are forwarded to the processor. However, in pass-through mode, the EPIC unit passes the raw interrupts from the global timers, MU (including DMA controllers), and I^2C to the $\overline{\text{L\_INT}}$ output signal.

If the interrupts from the global timers, MU (including DMA controllers), and I^2C are required to be reported internally to the processor, pass-through mode must be disabled. If pass-through mode is disabled, the internal and external interrupts are delivered using the priority and delivery mechanisms otherwise defined for the EPIC unit.

The pass-through mode is controlled by the GCR[M] bit (enabled when GCR[M] = 0). Note that when switching the EPIC unit from pass-through to mixed mode (either direct or serial), the programming note in Section 11.8, “Programming Guidelines,” may apply.

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11.5 EPIC Direct Interrupt Mode

In direct interrupt mode, the IRQ[0:4] signals represent external interrupts that are controlled and prioritized by the five IRQ vector/priority registers (IVPR0–IVPR4), and the five IRQ destination registers (IDR0–IDR4). The external interrupts can be programmed for either level- or edge-sensitive activation and either polarity. The direct interrupt mode is selected when EICR[SIE] = 0. Note that EICR[SIE] only has meaning when GCR[M] = 1 (direct mode is a subset of mixed-mode operation).

11.6 EPIC Serial Interrupt Interface

The serial interrupt mode is selected when EICR[SIE] = 1. Note that EICR[SIE] only has meaning when GCR[M] = 1 (serial interrupt mode is also a subset of mixed-mode operation). When the MPC8240 is in serial interrupt mode, 16 interrupt sources are supported through the following serial interrupt signals (that are multiplexed with the IRQ[0:3] input signals used in direct interrupt mode):

- Serial interrupt (S_INT) input signal
- Serial clock (S_CLK) output signal
- Serial reset (S_RST) output signal
- Serial frame ($\overline{\text{S\_FRAME}}$) output signal

The 16 serial interrupts are controlled and prioritized by the 16 serial vector/priority registers (SVPR0–15) and the 16 serial destination registers (SDR0–15).

11.6.1 Sampling of Serial Interrupts

When the EPIC unit is programmed for serial interrupts, 16 sources are sampled through the S_INT input signal. Each source (0–15) is allocated a one-cycle time slot in a sequence of 16 cycles in which to request an interrupt. The serial interrupt interface is clocked by the EPIC S_CLK output. This clock can be programmed to run at 1/2 to 1/14 of the MPC8240's SDRAM_CLK frequency by appropriately setting a 3-bit field in the serial interrupt configuration register. See Section 11.9.3, "EPIC Interrupt Configuration Register (EICR)." Extreme care should be used with regard to board noise problems if a frequency above 33 MHz is chosen. All references to the clock and to cycles in this subsection refer to the S_CLK clock.

When EPIC is switched to serial mode by setting EICR[SIE] = 1, a 16-cycle sequence begins 4 S_CLK cycles after EPIC outputs a 2-cycle high pulse through the S_RST output signal. The 16-cycle sequence keeps repeating; after going from interrupt source cycle count of 0, 1, 2, 3, 4,... 15, the count immediately returns to 0, 1, 2, and so on, with no S_CLK delays between cycle count 15 and the next cycle count 0. Each time the sequence count is pointing to interrupt source 0, the $\overline{\text{S\_FRAME}}$ signal is active. $\overline{\text{S\_FRAME}}$ is provided to guarantee synchronization between the MPC8240's EPIC unit and the serial interrupt source device.

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Note that initially, interrupt source 0 is sampled at the fifth S_CLK rising edge after S_RST negates. Also, once S_RST is asserted, it is not asserted again until after an EPIC reset, and the EPIC unit is subsequently programmed to serial mode again.

11.6.2 Serial Interrupt Timing Protocol

Figure 11.7 shows the relative timing for the serial interrupt interface signals.

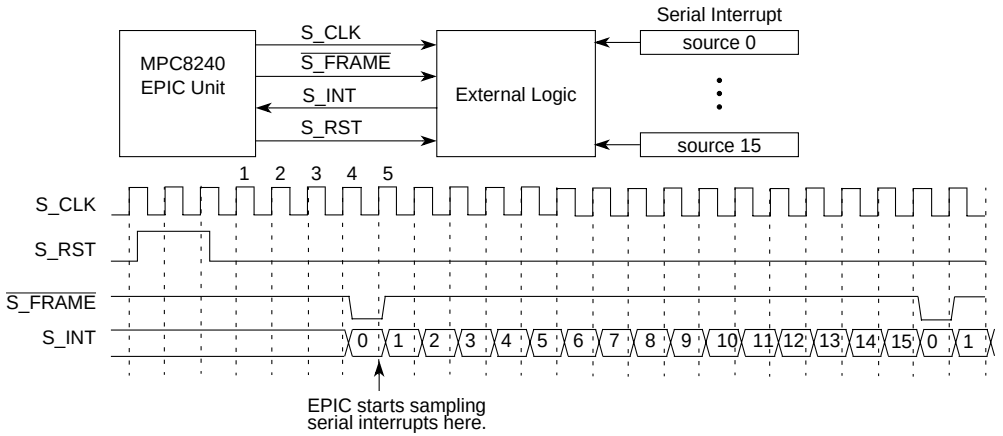

Figure 11-3. Serial Interrupt Interface Protocol

11.6.3 Edge/Level Sensitivity of Serial Interrupts

The interrupt detection is individually programmable for each source to be edge- or level-sensitive by writing the sense and polarity bits of the vector/priority register of the particular interrupt source. Refer to Section 11.3.6.1, “Interrupt Pending Register (IPR)—Non-programmable,” and the serial vector/priority register description in Section 11.9.8.1, “Direct & Serial Interrupt Vector/Priority Registers (IVPRs, SVPRs),” for more edge/level sensitivity information.

Note that for level-sensitive interrupts there is a potential race condition between an EOI (end of interrupt) command for a specific interrupt source and the sampling of the same specific interrupt source as inactive. Level-sensitive interrupts are cleared from an interrupt priority register only when sampled as inactive; therefore, a second interrupt for the same source may occur, although the specific interrupt has already been serviced.

Software can avoid this second interrupt by delaying the EOI command to the EPIC unit. Depending on the interrupt source device being serviced, one possible software method is to first clear the interrupt from the source before executing any other necessary read or write transactions to service the interrupt device. In any case, the delay should be no less than 16 serial clocks after clearing the interrupt at the source device.

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11.7 EPIC Timers

The MPC8240 has appropriate clock prescalers and synchronizers to provide a time base for the four global timers (0–3) of the EPIC unit. The global timers can be individually programmed to generate interrupts to the processor when they count down to zero and can be used for system timing or to generate regular periodic interrupts. Each timer has four registers for configuration and control:

- Global timer current count register (GTCCR)
- Global timer base count register (GTBCR)
- Global timer vector/priority register (GTVPR)
- Global timer destination register (GTDR)

The timers count at 1/8 the frequency of the SDRAM_CLK signals. The EPIC unit has a timer frequency reporting register (TFRR) that can be written by software to store the value of the timer frequency (as described in Table 11-11). Although this frequency is affected by the setting of the PLL_CFG[0:4] signals at reset, the system software must know the SDRAM_CLK frequency in order to set this value accurately. (There is no way to determine this frequency by simply reading an MPC8240 register.) The value written to TFRR does not affect the frequency of the timers.

Two of the timers, timer 2 and timer 3, can be set up to start automatically periodic DMA operations for DMA channels 0 and 1, respectively, without using the processor interrupt mechanism. In this case, the timer interrupt should be masked (GTVPR[M] = 1), and GTBCR[CI] should be cleared to start the counting. It is important to choose a rate for the timer so the time between the interrupts is longer than the time required to complete the DMA chain; otherwise, unpredictable operation occurs. To complete the initialization of the periodic DMA feature, the DMA channel must be configured for chaining mode and the DMR[PDE] for the appropriate channel must be set. See Section 8.3.2.2, “Periodic DMA Feature.”

11.8 Programming Guidelines

Accesses to the EPIC unit include interrupt and timer initialization, and reading the interrupt acknowledge register (IACK), which results in the EPIC unit returning the vector associated with the interrupt to be serviced. External interrupt sources IRQ[0:4] can be programmed for either level- or edge-sensitive activation and either polarity. Similarly, all 16 serial interrupt sources can be programmed for either level- or edge-sensitive activation and for either polarity.

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Most EPIC control and status registers are readable and return the last value written. The exceptions to this rule are as follows:

- EOI register, which returns zeros on reads
- Activity bit (A) of the vector/priority registers, which returns the value according to the status of the current interrupt source
- IACK register, which returns the vector of highest priority that is currently pending, or the spurious vector.
- Reserved bits, which normally return 0

Even though reserved fields return 0, this should not be assumed by the programmer. Reserved bits should always be written with the value they returned when read. Thus the registers with reserved fields should be programmed by reading the value, modifying the appropriate fields, and writing back the value.

The following guidelines are recommended when the EPIC unit is programmed in mixed mode (GCR[M] = 1):

- If the processor's memory management unit (MMU) is enabled, all EPIC registers must be located in a cache-inhibited and guarded area.
- The EPIC portion of the embedded utilities memory block (EUMB) must be set up appropriately. (Registers within the EUMB are located from 0x8000_0000 to 0xFDFF_FFFF.)
- The EPIC registers are described in this chapter in little-endian format. If the system is in big-endian mode, the bytes must be appropriately swapped by software.

In addition, the following initialization sequence is recommended:

1. Write the vector, priority and polarity values in each interrupt's vector/priority register leaving their M (mask) bit set. This is only required for interrupts to be used.
2. Set the processor current task priority register (PCTPR) value to zero.
3. Program the EPIC to mixed mode by setting GCR[M] = 1.
4. If using direct mode, set EICR[SIE] = 0. Otherwise, to use serial mode, program the S_CLK ratio field in EICR[R] for the desired interrupt frequency, and set EICR[SIE] = 1.
5. Clear the M bit in the vector/priority registers to be used.
6. Perform a software loop to clear all pending interrupts:
   — Load counter with FPR[NIRQ].
   — While (counter > 0), perform IACK and EOI's to guarantee all the interrupt pending and in-service registers are cleared.
7. Set the PCTPR value to desired priority.

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Depending on the interrupt system configuration, the EPIC unit may generate false interrupts to clear out interrupts either latched during power-up or due to resetting the EPIC unit. A spurious or real vector will be returned for an interrupt acknowledge cycle. See programming note below for the cases that return a real interrupt vector for a false interrupt.

NOTE:

Edge-sensitive false interrupts—Because edge-sensitive interrupts are not cleared until they are acknowledged and the default polarity/sense bits for all interrupts are set to edge-sensitive, it is possible for the EPIC unit to store detections of edges at power-up as pending interrupts. If software permanently sets the polarity/sense of an interrupt source to edge-sensitive, it may receive the vector for the interrupt source and not a spurious vector after software clears the mask bit. This can occur once for any edge-sensitive interrupt source when its mask is first cleared and the EPIC unit is in mixed mode.

To prevent having to handle a false interrupt for this case, software can clear the EPIC interrupt pending register of edges detected during power-up by first setting the polarity/sense bits of the interrupt source to level-sensitive as follows: high level if the line is a positive-edge source, low level if the line is a negative-edge source (and the mask bit should remain set). Software can then set the interrupt source's polarity/sense bits to the appropriate values.

Global timer false interrupts—If the EPIC unit has been initialized, the global timers were being used, and the EPIC unit is reset by setting the GCR[R] bit, the following occurs:

If the EPIC unit is reset when a GTCCR[T] = 1, a false interrupt is generated when that interrupt vector is unmasked after the reset sequence completes. By following the recommended initialization sequence in Steps 1–7 of this section during the initialization of the EPIC unit, this false interrupt can be handled without unexpected side effects. Unlike the above edge-sensitive case of false interrupts, there is no method of preventing having to handle this false interrupt.

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11.9 Register Definitions

The following sections describe the registers of the EPIC unit.

11.9.1 Feature Reporting Register (FRR)

The feature reporting register (FRR) provides information about the interrupt and processor configurations. It also contains controller version information. Note that this register is read-only. Figure 11-4 shows the bits in the FRR.

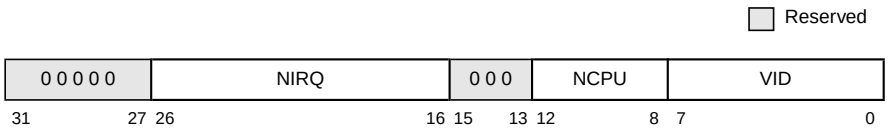

Figure 11-4. Feature Reporting Register (FRR)

Table 11-5 describes the bit settings for the FRR.

Table 11-5. FRR Field Descriptions—Offset 0x4_1000

Bits	Name	Reset Value	Description
31–27	—	All 0s	Reserved
26–16	NIRQ	0x017	Number of interrupts. This field contains the maximum number of interrupt sources supported. In the MPC8240, there are a maximum of 24 interrupts in use at one time: the 4 internal sources (I^2C, DMA (2), and MU), 4 timer sources and 16 external sources. A zero in this field corresponds to one interrupt, and so on. Thus the value of 0x017 corresponds to 24 interrupts.
15–13	—	All 0s	Reserved
12–8	NCPU	0x00	Number of CPUs. This field contains the number of the highest CPU supported. Because one CPU is supported by the MPC8240's EPIC unit, the value is zero corresponding to CPU 0.
7–0	VID	0x02	Version ID for this interrupt controller. This value reports the level of OpenPIC specification supported by this implementation. VID =2, representing version level 1.2 of OpenPIC, for the initial release of the MPC8240.

11.9.2 Global Configuration Register (GCR)

The GCR provides programming control for resetting the EPIC unit and for setting the external interrupts mode. Note that this register is read/write. Figure 11-5 shows the bits in the GCR.

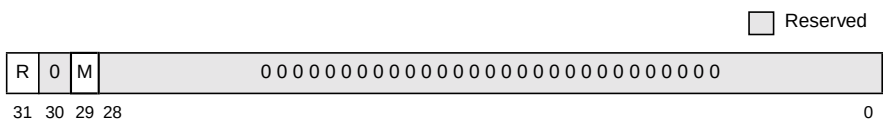

Figure 11-5. Global Configuration Register (GCR)

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Table 11-6 describes the bit settings for the GCR.

Table 11-6. GCR Field Descriptions—Offset 0x4_1020

Bits	Name	Reset Value	Description
31	R	0	Reset EPIC unit. Writing a one to this bit resets the EPIC controller logic. This bit is cleared automatically when this reset sequence is complete. Setting this bit causes the following: • All pending and in-service interrupts are cleared. • All interrupt mask bits are set. • All timer base count values are reset to zero and count inhibited. • The processor current task priority is reset to 0xF thus disabling interrupt delivery to the processor. • Spurious vector resets to 0xFF. • EPIC defaults to pass-through mode. • The serial clock ratio resets to 0x4. All other registers remain at their pre-reset programmed values.
30	—	0	Reserved
29	M	0	Mode 0 Pass-through mode. EPIC is disabled and interrupts detected on IRQ0 (active-high) are passed directly to the processor core. 1 Mixed-mode. When this bit is set, EICR[SIE] determines whether the EPIC unit is operating in direct or serial interrupts mode.
28–0	—	All 0s	Reserved

11.9.3 EPIC Interrupt Configuration Register (EICR)

The EICR provides programming control for the serial interrupt mode and the serial clock frequency. Note that this register is read/write. Figure 11-6 shows the bits in the EICR.

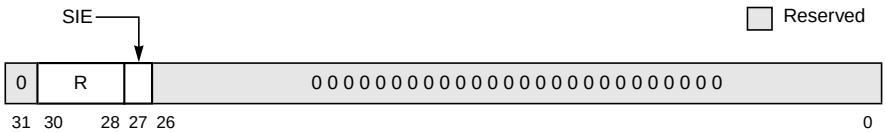

Figure 11-6. EPIC Interrupt Configuration Register (EICR)

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Table 11-7 describes the bit settings for the EICR.

Table 11-7. EICR Field Descriptions—Offset 0x4_1030

Bits	Name	Reset Value	Description
31	—	0	Reserved
30–28	R	0x4	Clock ratio. The S_CLK signal is driven by EPIC at a frequency of the SDRAM_CLK frequency divided by twice the value of this 3-bit field. The reset value of this field is 0x4. At this value, the S_CLK signal operates at 1/8th the frequency of the SDRAM_CLK signal. The allowable range of values for this field is between 1 and 7 resulting in a clock division ratio between 2 and 14 respectively. Note that an illegal value could result in spurious vectors returned when in either direct or serial mode.
27	SIE	0	Serial interrupt enable. This bit selects whether the MPC8240 IRQ signals are configured for direct interrupts or serial interrupts. The GCR[M] must be set to 1 (mixed-mode) in order for this bit value to have meaning. 0 Direct interrupts mode 1 Serial interrupts mode
26–0	—	All 0s	Reserved

11.9.4 EPIC Vendor Identification Register (EVI)

The EVI has specific read-only information about the vendor and the device revision. Figure 11-7 shows the bits in the EVI.

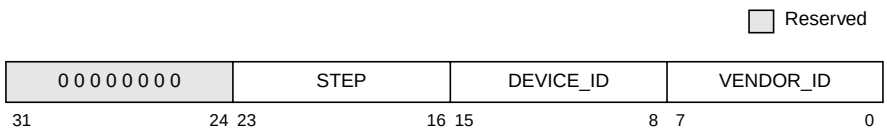

Figure 11-7. EPIC Vendor Identification Register (EVI)

Table 11-8 describes the bit settings for the EVI.

Table 11-8. EVI Register Field Descriptions—Offset 0x4_1080

Bits	Name	Reset Value	Description
31–24	—	All 0s	Reserved
23–16	STEP	0x01	Stepping. This indicates the stepping (silicon revision) for this device.
15–8	DEVICE_ID	All 0s	Device identification
7–0	VENDOR_ID	All 0s	Vendor identification. Because this value is zeros, the MPC8240 is considered to be a generic PIC-compliant device.

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11.9.5 Processor Initialization Register (PI)

The processor initialization register (PI) provides a mechanism for the software, through the EPIC unit, to cause a soft reset of the processor by asserting the *sreset* signal. Note that this register is read/write. Figure 11-8 shows the bits in the PI.

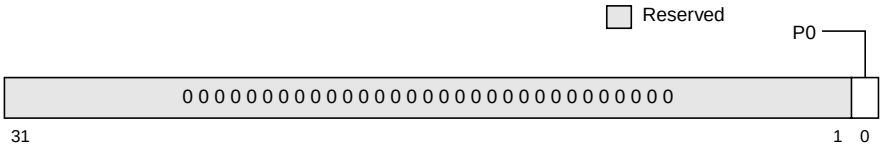

Figure 11-8. Processor Initialization Register (PI)

Table 11-9 describes the bit settings for the PI.

Table 11-9. PI Register Field Descriptions—Offset 0x4_1090

Bits	Name	Reset Value	Description
31–1	—	All 0s	Reserved
0	P0	0	Processor 0 soft reset 0 Default value 1 Setting this bit causes the EPIC unit to assert the internal $\overline{\text{sreset}}$ signal to the processor core, causing a soft reset exception. The $\overline{\text{sreset}}$ signal is edge-sensitive to the processor, but it is held active until a zero is written to P0. Thus, it should be cleared by software as soon as possible in the soft reset exception handler.

11.9.6 Spurious Vector Register (SVR)

The spurious vector register contains the 8-bit vector returned to the processor during an interrupt acknowledge cycle for the cases described in Section 11.3.5, “Spurious Vector Generation.” Note that this register is read/write. Figure 11-9 shows the bits in the SVR.

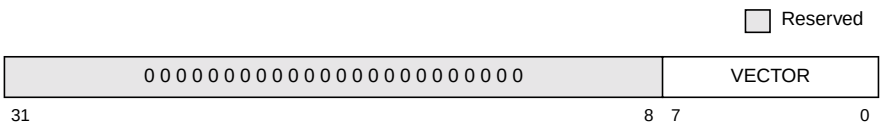

Figure 11-9. Spurious Vector Register (SVR)

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Table 11-10 describes the bit settings for the SVR.

Table 11-10. SVR Field Descriptions—Offset 0x4_10E0

Bits	Name	Reset Value	Description
31–8	—	All 0s	Reserved
7–0	VECTOR	0xFF	Spurious interrupt vector. The vector value in this field is returned when the interrupt acknowledge register (IACK) is read during a spurious vector fetch.

11.9.7 Global Timer Registers

This section describes the global timer registers. Note that each of the four timers (timer 0–timer 3) has four individual configuration registers (GTCCR*n*, GTBCR*n*, GTVPR*n*, GTDR*n*), but they are shown only once in this section.

11.9.7.1 Timer Frequency Reporting Register (TFRR)

The TFRR is written by software to report the clocking frequency of the EPIC timers. Note that although this register is read/write, the value in this register is ignored by the EPIC unit. Figure 11-10 shows the bits in the TFRR.

Figure 11-10. Timer Frequency Reporting Register (TFRR)

Table 11-11 describes the bit settings for the TFRR.

Table 11-11. TFRR Field Descriptions—Offset 0x4_10F0

Bits	Name	Reset Value	Description
31–0	TIMER_FREQ	All 0s	Timer frequency. This register is used to report the frequency of the clock source for the global timers (in ticks/seconds (Hz)) which is always the SDRAM_CLK signal. The timers operate at 1/8th the speed of the SDRAM_CLK signal. The register is only set by software. The value in this register does not affect the speed of the timers. The timers' speed is determined by the PLL_CFG[0–4] signals and the frequency of the PCI_SYNC_IN signal. The value may be written by the system initialization code after the SDRAM_CLK frequency has been determined by the firmware. The firmware can use information stored in the HID1 register and information about the actual processor frequency to determine the SDRAM_CLK frequency. However, in some cases, more system frequency information may be required.

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11.9.7.2 Global Timer Current Count Registers (GTCCRs)

The GTCRRs contain the current count for each of the four EPIC timers. Note that these registers are read-only. The address offsets from EUMBBAR for the GTCCRs are described in Table 11-12.

Table 11-12. EUMBBAR Offsets for GTCCRs

GTCCR	Offset
GTCCR0	0x4 _1100
GTCCR1	0x4_1140
GTCCR2	0x4_1180
GTCCR3	0x4_11C0

Figure 11-11 shows the bits of the GTCCRs.

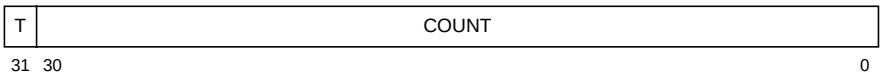

Figure 11-11. Global Timer Current Count Register (GTCCR)

Table 11-13 describes the bit settings for the GTCCRs.

Table 11-13. GTCCR Field Descriptions

Bits	Name	Reset Value	Description
31	T	0	Toggle. This bit toggles whenever the current count decrements to zero.
30–0	COUNT	All 0s	Current timer count. This 31-bit field is decremented while the GTBCR[CI] bit is zero. When the timer counts down to zero, this field is reloaded from the base count register, the toggle bit is inverted, and an interrupt is generated (provided it is not masked).

11.9.7.3 Global Timer Base Count Registers (GTBCRs)

The GTBCRs contain the base count for each of the four EPIC timers. This is the value reloaded into the GTCCRs when they count down to zero. Note that these registers are read/write. The address offsets from EUMBBAR for the GTBCRs are described in Table 11-14.

Table 11-14. EUMBBAR Offsets for GTBCRs

GTBCR	Offset
GTBCR0	0x4_1110
GTBCR1	0x4_1150
GTBCR2	0x4_1190
GTBCR3	0x4_11D0

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Figure 11-12 shows the bits of the GTBCRs.

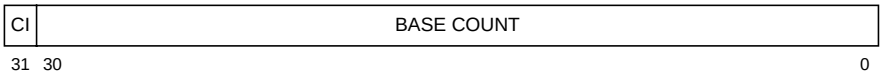

Figure 11-12. Global Timer Base Count Register (GTBCR)

Table 11-15 describes the bit settings for the GTBCRs.

Table 11-15. GTBCR Field Descriptions

Bits	Name	Reset Value	Description
31	CI	1	Count inhibit 0 Enables counting for this timer. 1 Inhibits counting for this timer.
30–0	BASE_COUNT	All 0s	Base count. This 31-bit field contains the base count used for this timer. When a value is written into this register and the CI bit transitions from a 1 to a 0, the base count value is copied into the corresponding current count register and the toggle bit is cleared.

11.9.7.4 Global Timer Vector/Priority Registers (GTVPRs)

The GTVPRs contain the interrupt vector and the interrupt priority for each of the four timers. In addition, they contain the mask and activity bits for each of the four timers. Note that these registers are read/write. The address offsets from EUMBBAR for the GTVPRs are described in Table 11-16.

Table 11-16. EUMBBAR Offsets for GTVPRs

GTVPR	Offset
GTVPR0	0x4_1120
GTVPR1	0x4_1160
GTVPR2	0x4_11A0
GTVPR3	0x4_11E0

Figure 11-13 shows the bits of the GTVPRs.

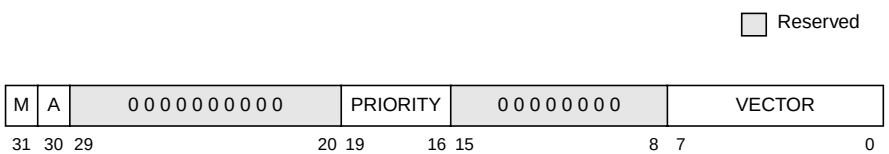

Figure 11-13. Global Timer Vector/Priority Register (GTVPR)

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Table 11-17 describes the bit settings for the GTVPRs.

Table 11-17. GTVPR Field Descriptions

Bits	Name	Reset Value	Description
31	M	1	Mask. Mask interrupts from this timer 0 If the mask bit is cleared while the corresponding IPR bit is set, $\overline{\text{int}}$ is asserted to the processor. 1 Further interrupts from this timer are disabled
30	A	0	Activity. Indicates that an interrupt has been requested or that it is in-service. Note that this bit is read-only. 0 No current interrupt activity associated with this timer. 1 The interrupt bit for this timer is set in the IPR or ISR. The VECTOR and PRIORITY values should not be changed while the A bit is set.
29–20	—	All 0s	Reserved
19–16	PRIORITY	0x0	Priority. This field contains the four-bit interrupt priority. The lowest priority is 0 and the highest is 15. A priority level of 0 disables interrupts from this timer.
15–8	—	0x00	Reserved
7–0	VECTOR	0x00	Vector. The vector value in this field is returned when the interrupt acknowledge register (IACK) is read, and the interrupt associated with this vector has been requested.

11.9.7.5 Global Timer Destination Registers (GTDRs)

Each GTDR indicates the destination for the timer's interrupt. Because the MPC8240's EPIC unit supports a single processor, the destination is always P0. Note that this register is read-only. The address offsets from EUMBBAR for the GTDRs are described in Table 11-18.

Table 11-18. EUMBBAR Offsets for GTDRs

GTDR	Offset
GTDR0	0x4_1130
GTDR1	0x4_1170
GTDR2	0x4_11B0
GTDR3	0x4_11F0

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Figure 11-14 shows the bits of the GTDRs.

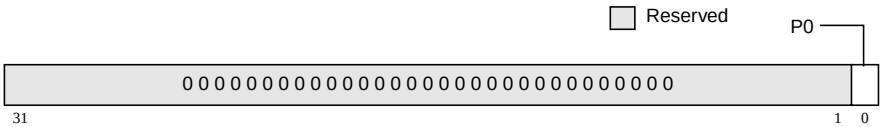

Figure 11-14. Global Timer Destination Register (GTDR)

Table 11-19 describes the bit settings for the GTDRs.

Table 11-19. GTDR Field Descriptions

Bits	Name	Reset Value	Description
31–1	–	All 0s	Reserved
0	P0	1	Processor 0—Timer interrupt is always directed to the processor core.

11.9.8 External (Direct and Serial), and Internal Interrupt Registers

This section describes the vector/priority and destination registers for the external (direct and serial), and internal (I^2C, DMA, and MU) interrupt sources.

11.9.8.1 Direct & Serial Interrupt Vector/Priority Registers (IVPRs, SVPRs)

The format for the IRQ0–4 (direct) vector/priority registers (IVPRs) is identical to that of the vector/priority registers for the 16 serial interrupts (SVPRs). Note that these registers are read/write.The address offsets from EUMBBAR for the IVPRs and SVPRs are shown in Table 11-20.

Table 11-20. EUMBBAR Offsets for IVPRs and SVPRs

IVPR	Offset	SVPR	Offset	SVPR	Offset
IVPR0	0x5_0200	SVPR0	0x5_0200	SVPR8	0x5_0300
IVPR1	0x5_0220	SVPR1	0x5_0220	SVPR9	0x5_0320
IVPR2	0x5_0240	SVPR2	0x5_0240	SVPR10	0x5_0340
IVPR3	0x5_0260	SVPR3	0x5_0260	SVPR11	0x5_0360
IVPR4	0x5_0280	SVPR4	0x5_0280	SVPR12	0x5_0380
		SVPR5	0x5_02A0	SVPR13	0x5_03A0
		SVPR6	0x5_02C0	SVPR14	0x5_03C0
		SVPR7	0x5_02E0	SVPR15	0x5_03E0

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Figure 11-15 shows the bits of the IVPRs and SVPRs.

Figure 11-15. Direct and Serial Interrupt Vector/Priority Registers (IVPR and SVPR)

Table 11-21 shows the bit settings for the IVPRs and SVPRs.

Table 11-21. IVPR and SVPR Field Descriptions

Bits	Name	Reset Value	Description
31	M	1	Mask. Masks interrupts from this source. 0 If the mask bit is cleared while the corresponding IPR bit is set, $\overline{\text{int}}$ is asserted to the processor. 1 Further interrupts from this source are disabled
30	A	0	Activity. Indicates that an interrupt has been requested or that it is in-service. Note that this bit is read-only. 0 No current interrupt activity associated with this source. 1 The interrupt bit for this source in the IPR or ISR is set. The VECTOR, PRIORITY, P (polarity), or S (sense) values should not be changed while the A bit is set, except to clear an old interrupt.
29–24	—	All 0s	Reserved
23	P	0	Polarity. This bit sets the polarity for the external interrupt. 0 Polarity is active-low or negative-edge triggered 1 Polarity is active-high or positive-edge triggered
22	S	0	Sense. This bit sets the sense for external interrupts. 0 The external interrupt is edge-sensitive. 1 The external interrupt is level-sensitive.
21–20	—	All 0s	Reserved
19–16	PRIORITY	0x0	Priority. This field contains the four-bit interrupt priority. The lowest priority is 0 and the highest is 15. A priority level of 0 disables interrupts from this source.
15–8	—	0x00	Reserved
7–0	VECTOR	0x00	Vector. The vector value in this field is returned when the interrupt acknowledge register (IACK) is read and the interrupt associated with this vector has been requested.

11.9.8.2 Direct & Serial Interrupt Destination Registers (IDRs, SDRs)

The IDR and SDR registers indicate the destination for each external interrupt source. Because the MPC8240 is a single-processor device, the destination is always P0. Note that these registers are read-only. The address offsets from EUMBBAR for the IDRs and SDRs are shown in Table 11-22.

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Table 11-22. EUMBBAR Offsets for IDRs and SDRs

IDR	Offset	SDR	Offset	SDR	Offset
IDR0	0x5_0210	SDR0	0x5_0210	SDR8	0x5_0310
IDR1	0x5_0230	SDR1	0x5_0230	SDR9	0x5_0330
IDR2	0x5_0250	SDR2	0x5_0250	SDR10	0x5_0350
IDR3	0x5_0270	SDR3	0x5_0270	SDR11	0x5_0370
IDR4	0x5_0290	SDR4	0x5_0290	SDR12	0x5_0390
		SDR5	0x5_02B0	SDR13	0x5_03B0
		SDR6	0x5_02D0	SDR14	0x5_03D0
		SDR7	0x5_02F0	SDR15	0x5_03F0

Figure 11-16 shows the bits of the IDRs and SDRs.

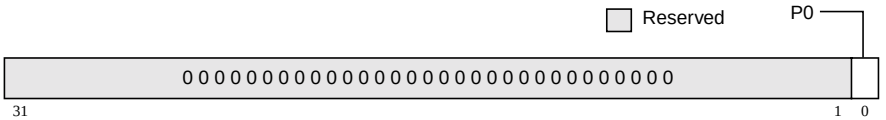

Figure 11-16. Direct and Serial Destination Registers (IDR and SDR)

Table 11-23 shows the bit settings for the IDRs and SDRs.

Table 11-23. IDR and SDR Field Descriptions

Bits	Name	Reset Value	Description
31–1	—	All 0s	Reserved
0	P0	1	Processor 0. Direct and serial interrupts always directed to the processor.

11.9.8.3 Internal (I^2C, DMA, MU) Interrupt Vector/Priority Registers (IIVPRs)

The IIVPRs have the same format and field descriptions as the GTVPRs, except that they apply to the internal MPC8240 interrupt sources—the I^2C unit, DMA unit (2 channels), and MU. See Section 11.9.7.4, “Global Timer Vector/Priority Registers (GTVPRs),” for a complete description of the GTVPRs.

11.9.8.4 Internal (I^2C, DMA or MU) Interrupt Destination Registers (IIDRs)

The IIDRs have the same format and field descriptions as the IDRs (and SDRs), except that they apply to the internal MPC8240 interrupt sources—the I^2C unit, DMA unit (2 channels), and MU. See Section 11.9.8.2, “Direct & Serial Interrupt Destination Registers (IDRs, SDRs),” for a complete description of the IDRs.

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11.9.9 Processor-Related Registers

This section describes the processor-related EPIC registers.

11.9.9.1 Processor Current Task Priority Register (PCTPR)

Software should write the priority of the current processor task in the PCTPR. The EPIC unit uses this value to compare with the priority of incoming interrupts. The $\overline{int}$ signal is asserted to the processor core if the incoming interrupt is not masked, has a greater priority than that assigned in the PCTPR and ISR, and is greater than the priority of the other incoming interrupts. Priority levels from 0 (lowest) to 15 (highest) are supported. Setting the task priority to 15 masks all interrupts to the processor. The PCTPR is initialized to 0x0000_000F when the MPC8240 is reset, or when the P0 bit of the processor initialization register is set to one. Note that this register is read/write. Figure 11-17 shows the bits of the PCTPR.

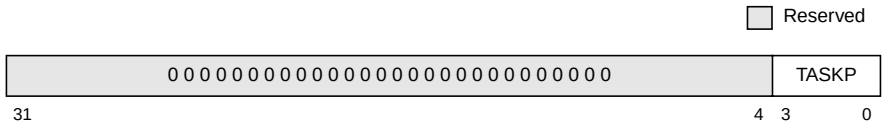

Figure 11-17. Processor Current Task Priority Register (PCTPR)

Table 11-24 shows the bit settings for the PCTPR.

Table 11-24. PCTPR Field Descriptions—Offset 0x6_0080

Bits	Name	Reset Value	Description
31–4	—	All 0s	Reserved
3–0	TASKP	0xF	Task priority. This field is set 0 to 15, where 15 corresponds to the highest priority for processor tasks. When PCTPR[TASKP] = 0xF, no interrupts will be signalled to the processor.

11.9.9.2 Processor Interrupt Acknowledge Register (IACK)

The interrupt acknowledge mechanism on the MPC8240 consists of a read from the memory-mapped interrupt acknowledge register (IACK) in the EPIC unit. Reading the IACK returns the interrupt vector corresponding to the highest priority pending interrupt. Reading IACK also has the following side effects:

- The associated bit in the IPR is cleared (if it is configured as edge-sensitive).
- The ISR is updated.
- The internal $\overline{int}$ signal is negated.

Reading IACK when there is no interrupt pending returns the spurious vector value. Note that this register is read-only.

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Figure 11-18 shows the bits of the IACK.

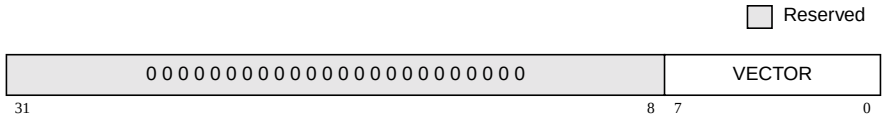

Figure 11-18. Processor Interrupt Acknowledge Register (IACK)

Table 11-25 shows the bit settings of the IACK.

Table 11-25. IACK Field Descriptions—Offset 0x6_00A0

Bits	Name	Reset Value	Description
31–8	—	All 0s	Reserved
7–0	VECTOR	0x0	Interrupt vector. When this register is read, this field returns the vector of the highest pending interrupt in the EPIC unit.

11.9.10 Processor End-of-Interrupt Register (EOI)

A write to the EOI signals the end of processing for the highest priority interrupt currently in service by the processor. The write to EOI updates the ISR by retiring the highest priority interrupt. Data values written to this register are ignored, and zero is assumed. Reading this register returns zeros (this register is considered write-only). Figure 11-19 shows the bits of the EOI.

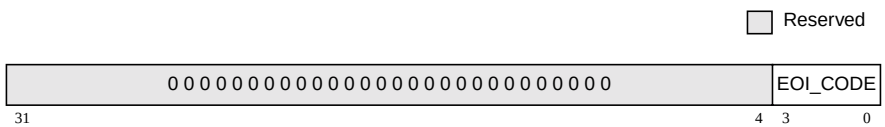

Figure 11-19. Processor End of Interrupt Register (EOI)

Table 11-26 shows the bit settings for the EOI.

Table 11-26. EOI Field Descriptions—Offset 0x6_00B0

Bits	Name	Reset Value	Description
31–4	—	—	Reserved
3–0	EOI_CODE	—	0000

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Chapter 12
Central Control Unit

The MPC8240 uses internal buffering to store addresses and data moving through it and to maximize opportunities for concurrent operations. A central control unit directs the flow of transactions through the MPC8240 performing internal arbitration and coordinating the internal and external snooping. This chapter describes the internal buffering and arbitration logic of the MPC8240 central control unit (CCU). See Chapter 5, “PowerPC Processor Core,” for more detailed information on the kinds of internal transactions that are snooped by the processor.

Note that the buffers described in this chapter don’t include the internal data bus buffers in the memory interface unit that are used for improved electrical performance (speed and loading). For more information on these buffers, see Chapter 6, “MPC8240 Memory Interface.” Note also that in this chapter, the terminology local memory is used to denote memory controlled by this MPC8240.

12.1 Internal Buffers

For most operations of the MPC8240, data is latched internally in one of eight data buffers. Each of the eight internal data buffers has a corresponding address buffer. An additional buffer stores the address of the most recent (or current) processor access to local memory. All transactions entering the MPC8240 have their addresses stored in the internal address buffers. The address buffers allow the addresses to be snooped as other transactions attempt to go through the MPC8240. This is especially important for write transactions that enter the MPC8240 because memory can be updated out-of-order with respect to other transactions.

The CCU directs the bus snooping (provided snooping is enabled) for each PCI access to local memory to enforce coherency between the PCI-initiated access and the L1 data cache. All addresses are snooped in the order that they are received from the PCI bus. For systems that do not require hardware-enforced coherency, snooping can be disabled by setting the CF_NO_SNOOP parameter in PICR2. Note that if snooping is disabled, the PCI exclusive access mechanism (the $\overline{\text{LOCK}}$ signal) does not affect the transaction. That is, the transaction will complete, but the processor will not be prohibited from accessing the cache line.

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The MPC8240 supports critical word first burst transactions (double-word aligned) from the processor core. The CCU transfers this double word of data first followed by double words from increasing addresses wrapping back to the beginning of the eight-word block, as required.

Figure 12-1 depicts the organization of the internal buffers.

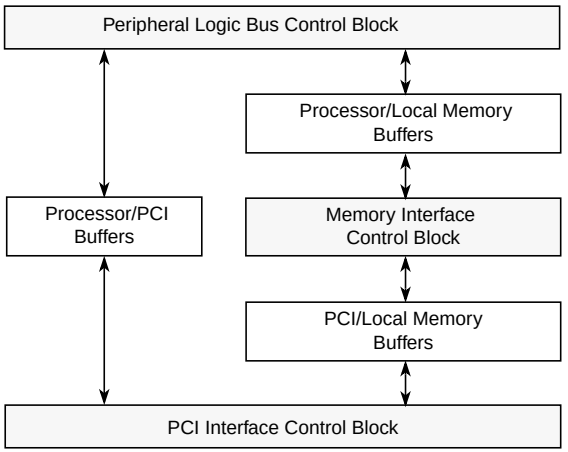

Figure 12-1. MPC8240 Internal Buffer Organization

12.1.1 Processor Core/Local Memory Buffers

Because the MPC8240 has a shared internal data bus between the processor and local memory, for most cases it is unnecessary to buffer data transfers between these devices. However, there is a 32-byte copyback buffer which is used for temporary storage of the following:

- L1 copyback data due to snooping PCI-initiated reads from memory
- sub-double-word, single-beat writes when read-modify-write (RMW) parity is used
- processor burst writes when ECC is enabled

The copyback buffer can only be in one of two states—invalid or modified with respect to local memory. Since the buffer is only used for burst write data, the entire cache line in the buffer is always valid if any part of the cache line is valid.

Figure 12-2 shows the address and data buffers between the peripheral logic bus and the local memory bus.

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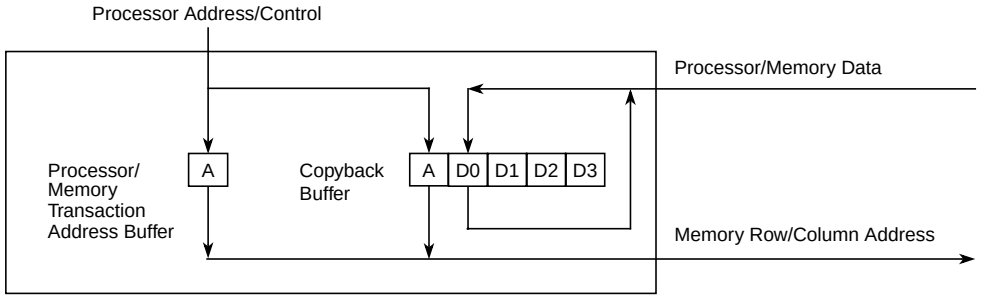

Figure 12-2. Processor/Local Memory Buffers

In the case of a snoop for a PCI read from local memory that causes an L1 copyback, the copyback data is simultaneously latched in the copyback buffer and the PCI-read-from-local-memory buffer (PCMRB). When the L1 copyback is complete, the data is forwarded to the PCI agent from the PCMRB. The MPC8240 flushes the data in the copyback buffer to local memory at the earliest available opportunity.

For processor burst writes to memory with ECC enabled, the MPC8240 uses the copyback buffer as a temporary holding area while it generates the appropriate ECC codes to send to memory.

After the copyback buffer has been filled, the data remains in the buffer until the local memory bus is available to flush the copyback buffer contents to local memory. During the time that modified data waits in the copyback buffer, all transactions to local memory space are snooped against the copyback buffer. All PCI-initiated transactions that hit in the copyback buffer cause the copyback buffer to have the highest priority for being flushed out to main memory.

12.1.2 Processor/PCI Buffers

There are three data buffers for processor accesses to PCI—one 32-byte processor-to-PCI-read buffer (PRPRB) for processor reads from PCI, and two 16-byte processor-to-PCI-write data buffers (PRPWBs) for processor writes to PCI.

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Figure 12-3 shows the address and data buffers between the peripheral logic bus and the PCI bus.

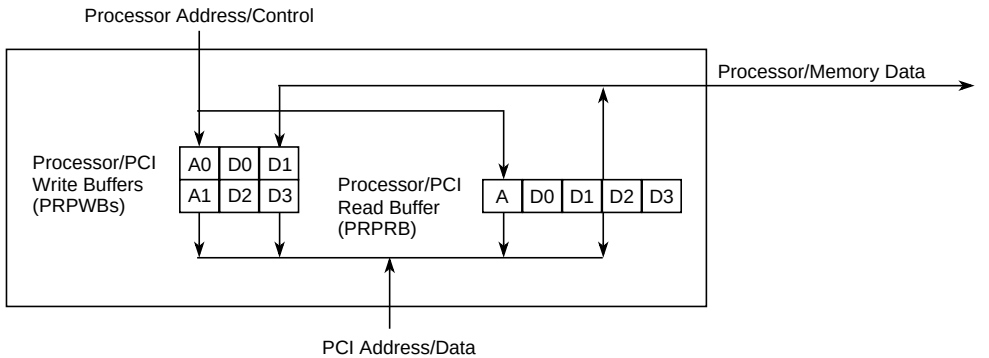

Figure 12-3. Processor/PCI Buffers

12.1.2.1 Processor-to-PCI-Read Buffer (PRPRB)

Processor reads from PCI require buffering for two primary reasons. First, the processor bus uses a critical-word-first protocol, while the PCI bus uses a zero-word-first protocol. The MPC8240 requests the data zero-word-first, latches the requested data, and then delivers the data to the processor core critical-word-first.

The second reason is that if the target for a processor read from PCI disconnects part way through the data transfer, the MPC8240 may have to handle a local memory access from an alternate PCI master before the disconnected transfer can continue.

When the processor requests data from PCI space, the data received from PCI is stored in the PRPRB until all requested data has been latched. The CCU does not terminate the address tenure of the internal transaction until all requested data is latched in the PRPRB. If the PCI target disconnects in the middle of the data transfer and an alternate PCI master acquires the bus and initiates a local memory access, the CCU retries the ongoing internal transaction with the processor core so that the incoming PCI transaction can be snooped. A PCI-initiated access to local memory may require a snoop transaction on the internal peripheral logic bus and also a copyback. The CCU does not provide the data to the peripheral logic bus (for the processor to PCI read transaction) until all outstanding snoops for PCI writes to local memory have completed.

Note that if a processor read from a PCI transaction is waiting for a PCMWB snoop to complete (that is, data has been latched into PRPRB from the PCI bus but has not yet returned to the processor—perhaps the processor must retry the read), all subsequent requests for PCI writes to local memory will be retried on the PCI bus.

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The PCI interface of the MPC8240 continues to request mastership of the PCI bus until the processor's original request is completed. When the next processor transaction starts, the address is snooped against the address of the previous transaction (in the internal address buffer) to verify that the same cache line is being requested. Once all the requested data is latched, and all PCI write to local memory snoops have completed, the CCU completes the data transfer to the processor.

For example, if the processor initiates a critical-word-first burst read, starting with the second double word of a cache line, the read on the PCI bus begins with the cache-line-aligned address. If the PCI target disconnects after transferring the first half of the cache line, the MPC8240 re-arbitrates for the PCI bus, and when granted, initiates a new transaction with the address of the third double word of the line. If an alternate PCI master requests data from local memory while the MPC8240 is waiting for the PCI bus grant, the central control unit internally retries the processor core transaction to allow the PCI-initiated transaction to be snooped by the processor core. When the processor snoop is complete, the subsequent processor transaction is compared to the latched address and attributes of the PRPRB to ensure that the processor is requesting data for the same cache line. After all data requested by the processor is latched in the PRPRB, the data is transferred to the processor, completing the transaction.

12.1.2.2 Processor-to-PCI-Write Buffers (PRPWBs)

There are two 16-byte buffers for processor writes to PCI. These buffers can be used together as one 32-byte buffer for processor burst writes to PCI or separately for single-beat writes to PCI. This allows the MPC8240 to support both burst transactions and streams of single-beat transactions. The MPC8240 performs store gathering (if enabled) of sequential accesses within the 16-byte range that comprises either the first or second half of the cache line. All transfer sizes are gathered if enabled (PICR1[ST_GATH_EN] = 1).

The internal buffering minimizes the effect of the slower PCI bus on the higher-speed peripheral logic bus that interfaces to the processor core. After the processor write data is latched internally, the internal peripheral logic bus is available for subsequent transactions, and it doesn't need to wait for the write to the PCI target to complete. Note that both PCI memory and I/O accesses are buffered. Device drivers must take into account that writes to I/O devices on the PCI bus are posted. The processor may believe that the write has completed while the MPC8240 is still trying to acquire mastership of the PCI bus.

If the processor core initiates a burst write to PCI, the processor data transfer is delayed until all previous writes to PCI are completed, and then the burst data from the processor fills the two PRPWBs. The address and transfer attributes are stored in the first address buffer.

For a stream of single-beat writes, the data for the first transaction is latched in the first buffer and the MPC8240 initiates the transaction on the PCI bus. The second single-beat write is then stored in the second buffer. For subsequent single-beat writes, store gathering is possible if the incoming write is to sequential bytes in the same half cache line as the

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previously latched data. Store gathering is only used for writes to PCI memory space not for writes to PCI I/O space. The store gathering continues until the buffer is scheduled to be flushed or until the processor issues a synchronizing transaction.

For example, if both PRPWBs are empty and the processor issues a single-beat write to PCI, the data is latched in the first buffer and the PCI interface of the MPC8240 requests mastership of the PCI bus for the transfer. The data for the next processor-to-PCI write transaction is latched in the second buffer, even if the second transaction's address falls within the same half cache line as the first transaction. While the PCI interface is busy with the first transfer, any sequential processor single-beat writes within the same half cache line as the second transfer are gathered in the second buffer until the PCI bus becomes available.

12.1.3 PCI/Local Memory Buffers

There are four data buffers for PCI accesses to local memory—two 32-byte PCI-to-local memory read buffers (PCMRBs) for PCI reads from local memory and two 32-byte PCI-to-local memory write buffers (PCMWBs) for PCI writes to local memory. Figure 12-4 shows the address and data buffers between the PCI bus and the local memory.

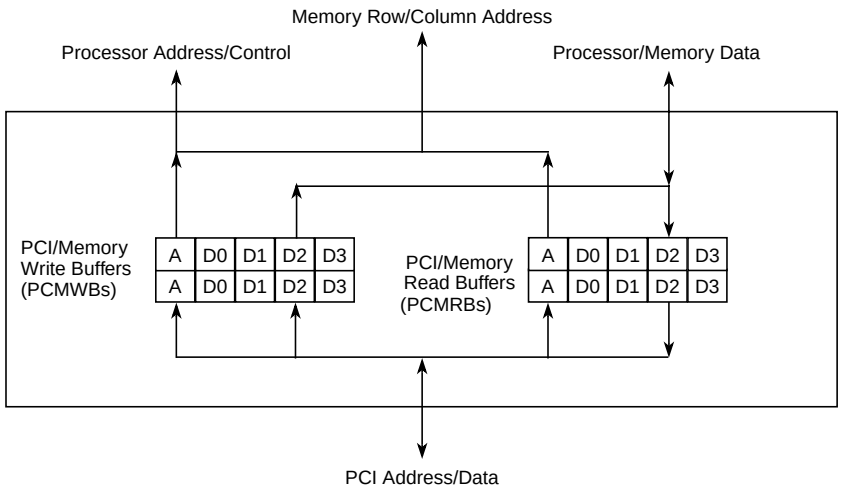

Figure 12-4. PCI/Local Memory Buffers

Note that many PCI accesses to local memory are snooped on the peripheral logic bus to ensure coherency between the PCI bus, local memory, and the L1 cache of the processor. All snoops for PCI accesses to local memory are performed strictly in order.

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Table 12-1 summarizes the snooping behavior of PCI accesses to local memory that hit in one of the internal buffers.

Table 12-1. Snooping Behavior Caused by a Hit in an Internal Buffer

PCI Transaction	Hit in Internal Buffer	Snoop Required
Read	Copyback	Yes
Read (not locked)	PCMRB	No
Read (first access of a locked transfer)[1]	PCMRB	Yes
Read (not locked)	PCMWB	No
Read (first access of a locked transfer)[1]	PCMWB	Yes
Write	Copyback	Yes
Write	PCMRB	Yes
Write	PCMWB	No

[1] Only reads can start an exclusive access (locked transfer). The first locked transfer must be snooped so that the cache line in the L1 is invalidated.

12.1.3.1 PCI to Local Memory Read Buffering

The following subsections describe the PCMRB buffer and capability of the MPC8240 to perform speculative PCI reads from local memory.

12.1.3.1.1 PCI-to-Local-Memory-Read Buffers (PCMRBs)

When a PCI device initiates a read from local memory, the address is snooped on the peripheral logic bus (provided snooping is enabled). If the memory interface is available, the memory access is started simultaneously with the snoop. If the snoop results in a hit in the L1 cache, the MPC8240 cancels the local memory access.

Depending on the outcome of the snoop, the requested data is latched into either one of the 32-byte PCI-to-local-memory-read buffers (PCMRBs), or into both the copyback buffer and a PCMRB (as described in Section 12.1.1, “Processor Core/Local Memory Buffers”) as follows:

- If the snoop hits in the L1, the copyback data is written to the copyback buffer and copied to the PCMRB when the copyback buffer is flushed to memory. The data is forwarded to the PCI bus from the PCMRB, and to local memory from the copyback buffer.
- If the snoop does not hit in the L1, a PCMRB is filled from local memory with the entire corresponding cache line, regardless of whether the starting address of the PCI-initiated transaction was at a cache-line boundary. The data is forwarded to the PCI bus from the PCMRB as the PCMRB is loaded (the CCU doesn’t wait for the PCMRB to be full).

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The data is forwarded to the PCI bus as soon as it is received, not when the complete cache line has been written into a PCMRB. The addresses for subsequent PCI reads are compared to the existing address, so if the new access falls within the same cache line and the requested data is already latched in the buffer, the data can be forwarded to PCI without requiring a snoop or another memory transaction.

If a PCI write to local memory hits in a PCMRB, the PCMRB is invalidated and the address is snooped on the peripheral logic bus. If the processor core accesses the address in the PCMRB, the PCMRB is invalidated.

12.1.3.1.2 Speculative PCI Reads from Local Memory

To minimize the latency for large block transfers, the MPC8240 provides the ability to perform speculative PCI reads from local memory. When speculative reading is enabled (or a PCI read multiple transfer requests data word 2 of a cache line), the MPC8240 starts the snoop of the next sequential cache-line address. After the speculative snoop response is known and the MPC8240 has completed the current PCI read, the data at the speculative address is fetched from local memory and loaded into the other PCMRB in anticipation of the next PCI request.

Speculative PCI reads are enabled on a per access basis by using the PCI memory-read-multiple command. Speculative PCI reads can be enabled for all PCI memory read commands (memory-read, memory-read-multiple, and memory-read-line) by setting bit 2 in PICR1.

The MPC8240 starts the speculative read operation only under the following conditions:

- PICR1[2] = 1 or the current PCI read access is from a memory read-multiple command.
- No internal buffer flushes are pending.
- The address does not cross a 4-Kbyte boundary.
- The access is not a locked transaction.
- There are no outstanding configuration register accesses from the processor.
- The access is to local (S)DRAM space. The MPC8240 does not perform speculative reads from local ROM space.

12.1.3.2 PCI-to-Local-Memory-Write Buffers (PCMWBs)

For PCI write transactions to local memory, the MPC8240 employs two PCMWBs. The PCMWBs hold up to one cache line (32 bytes) each. Before PCI data is transferred to local memory, the address must be snooped on the peripheral logic bus (if snooping is enabled). The buffers allow for the data to be latched while waiting for a snoop response. The write data can be accepted without inserting wait states on the PCI bus. Also, two buffers allow a PCI master to write to one buffer, while the other buffer is flushing its contents to local memory. Both PCMWBs are capable of gathering for writes to the same cache line.

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If the snoop on the peripheral logic bus hits modified data in the L1 cache, the snoop copyback data is merged with the data in the appropriate PCMWB, and the full cache line is sent to memory. For the PCI memory-write-and-invalidate command, a snoop hit in the L1 cache invalidates any modified cache line without requiring a copyback.

Note that a PCI transaction that hits in either of the PCMWBs does not require a snoop on the peripheral logic bus. However, if a PCI write address hits in a PCI-read-from-local-memory buffer (PCMRB), the CCU invalidates the PCMRB and snoops the address on the peripheral logic bus.

When the PCI write is complete and the snooping is resolved, the data is flushed to memory at the first available opportunity.

For a stream of single-beat writes, the data for the first transaction is latched in the first buffer and the CCU initiates the snoop transaction on the peripheral logic bus. For subsequent single-beat writes, gathering is possible if the incoming write is to the same cache line as the previously latched data. Gathering in the first buffer can continue until the buffer is scheduled to be flushed, or until a write occurs to a different address. If there is valid data in both buffers, further gathering is not supported until one of the buffers has been flushed.

12.2 Internal Arbitration

The MPC8240 performs arbitration internally for the internal shared processor/memory data bus. Note that all processor-to-PCI transactions are performed strictly in-order with respect to the MPC8240. Also, all snoops for PCI accesses to local memory are performed in order (if snooping is enabled).

12.2.1 Arbitration Between PCI and DMA Accesses to Local Memory

For the purposes of the CCU, the two DMA channels of the MPC8240 DMA controller function as PCI devices on the MPC8240 as shown in Figure 12-5.

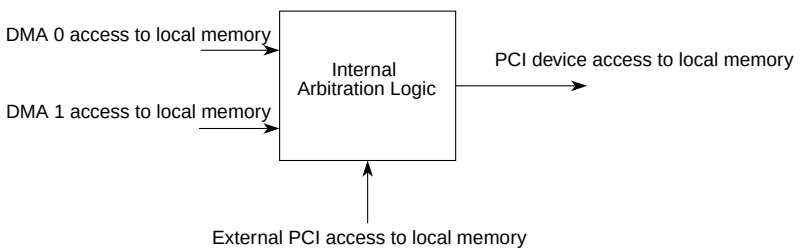
DMA 0 access to local memory
DMA 1 access to local memory
Internal
Arbitration Logic
PCI device access to local memory
External PCI access to local memory

Figure 12-5. PCI/DMA Arbitration for Local Memory Accesses

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The priority between simultaneous accesses from the external PCI bus and the DMA controller to the shared processor/memory data bus is controlled by the arbiter shown in Figure 12-5 as follows:

- External PCI masters always have greater priority than DMA accesses.
- The priority between DMA channels 0 and 1 is round-robin.

If a DMA channel is currently accessing local memory, then accesses from external PCI devices are retried. Rearbitration within this arbiter between the DMA channels and external PCI masters occurs at DMA transaction boundaries. DMA transaction boundaries for some DMA-initiated transactions are affected by the setting of the DMR[LMDC] value as described in the following subsections. Also see Section 8.7.1, “DMA Mode Registers (DMRs),” for detailed information about DMR[LMDC].

12.2.1.1 DMA Transaction Boundaries for Memory/Memory Transfers

DMA transaction boundaries for local memory to local memory transfers occur as follows:

- When DMR[LMDC] is 0b00
  - — After each cache line write for DMA writes to local memory
  - — After up to two cache line reads for DMA reads from local memory
- When DMR[LMDC] is nonzero, DMA transaction boundaries occur after the transfer of a single cache line for both reads and writes to local memory.

Note that depending on the timing of an incoming PCI transfer, if a DMA channel is performing local memory to local memory transfers, the external PCI master may be repeatedly retried. Aside from affecting the DMA transaction boundaries, the value of the DMR[LMDC] also increases the time delay between subsequent DMA accesses to local memory. To reduce the occurrence of PCI retries in this case, software can increase the value of the DMR[LMDC] value causing more latency in between DMA accesses to local memory, and giving a greater probability that the PCI access will gain access to the processor/memory data bus.

12.2.1.2 DMA Transaction Boundaries for Memory to PCI Transfers

DMA transaction boundaries for local memory to PCI transfers occur as follows:

- When DMR[LMDC] is 0b00, DMA transaction boundaries occur after the streaming (reads) of up to 4 Kbytes from local memory.
- When DMR[LMDC] is nonzero, DMA transaction boundaries occur after the transfer of a single cache line for reads from local memory.

In order for a DMA channel to stream (up to 4 Kbytes) from local memory to the PCI bus, the PCI bus must be available to sustain the streaming. Note that the latency timer parameter in the PCI latency timer register (PLTR) can affect the streaming of data to the PCI bus. If the latency timer is set to be a shorter period than the time required to transfer

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4 Kbytes, then the PCI stream terminates when another PCI master is granted mastership of the PCI bus. The latency timer parameter in the PCI latency timer register (PLTR) is further described in Section 4.2.6, “Latency Timer—Offset 0x0D.”

As described for memory to memory transfers, nonzero values of the DMR[LMDC] also increase the time delay between subsequent DMA accesses to local memory for memory to PCI transfers.

12.2.1.3 DMA Transaction Boundaries for PCI–Memory Transfers

The DMA transaction boundaries for DMA writes to local memory from the PCI bus occur after the transfer of a single cache line for all values of DMR[LMDC]. As described for the other cases, nonzero values of the DMR[LMDC] increase the time delay between subsequent DMA accesses to local memory for PCI to local memory transfers.

12.2.1.4 PCI and DMA Reads from Slow Memory/Port X

As described in Section 7.4.3.2, “Target-Initiated Termination,” if the MPC8240 can not read the first data beat of a burst from local memory within 16 PCI clock cycles, the transaction is considered to have timed out internally and as a target, the MPC8240 terminates the transaction with a retry. In this case, the CCU continues the access to memory (as a speculative PCI read) in anticipation of the PCI device requesting the same transaction at a later time. When the PCI device attempts the read again, the transaction is rearbitrated with DMA transactions within the PCI interface as a new transaction (not speculative). If the data has been successfully read into the PCMRB from memory, the CCU provides the data to the PCI bus.

Similarly, the DMA controller attempts to complete a read from local memory in 32 PCI clock cycles. If the read does not complete within that time, the CCU continues the access to memory (as a speculative PCI read in Table 12-2) on behalf of the DMA channel, but the DMA transaction is considered to have timed out within the PCI interface. After allowing for rearbitration within the PCI interface unit of the MPC8240, the DMA channel attempts the read again (not considered speculative). If the read has been completed by the MPC8240, the CCU provides the data to the DMA unit.

12.2.2 Internal Arbitration Priorities

The overall arbitration for the processor/memory data bus employs the priority scheme shown in Table 12-2. Note that because the DMA channels function as PCI devices with respect to the processor/memory data bus, the entries for PCI reads and writes in the table also implicitly include the cases for DMA reads and writes and they are arbitrated as described in Section 12.2.1, “Arbitration Between PCI and DMA Accesses to Local Memory.”

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The arbitration boundaries for access to the processor/memory data bus shown in Table 12-2 occur on a cache-line basis. Thus, after every cache line is transferred, requests for access to the processor/memory bus are ranked by the priorities shown in the table.

Note that the first access of a multi-cache-line read (generated by a PCI master or the DMA unit) is classified as a PCI read in the table. If snooping is enabled, subsequent reads in multi-cache-line accesses are classified as speculative PCI reads in the table (with a priority of 10) until the snoop completes. When the snoop completes, the access changes to a priority of 2. If snooping is disabled, the subsequent reads in multi-cache-line accesses are classified as speculative PCI reads with a priority of 2.

Table 12-2. Internal Arbitration Priorities

Priority	Operation
1	A high-priority copyback buffer flush due to one of the following: A PCI access to local memory hits in the copyback buffer. A processor burst write to local memory with ECC enabled hits an address in the PCMWB (with snoop not complete). A processor burst write to local memory with ECC enabled hits an address in the PCMRB (with snoop not complete).
1.5	Pipelined processor reads or writes to local memory (only occurs when snooping is disabled).
2	A PCI read or speculative PCI read from local memory with snoop complete (or snooping disabled). See Section 12.2.3, “Guaranteeing Minimum PCI Access Latency to Local Memory.”
3	A processor read from local memory
4	A high priority PCMWB flush due to one of the following: A PCI read hits in the PCMWB. The PCMWB is full and another PCI write to local memory starts. A processor to local memory read hits in the PCMWB. A processor to local memory single-beat write hits in the PCMWB.
5	A medium priority copyback buffer flush due to one of the following: A processor read hits in the copyback buffer. A processor single-beat write hits in the copyback buffer. The copyback buffer is full and new data needs to be written to it.
6	Normal processor transfers including the following: A processor write to local memory A snoop copyback due to a PCI write snoop A processor read from PCI A processor write to PCI A copyback buffer fill
7	A PCI read from local memory with snoop not complete. See Section 12.2.3, “Guaranteeing Minimum PCI Access Latency to Local Memory.”
8	A low-priority copyback buffer flush
9	A low-priority PCMWB flush
10	A PCMRB prefetch from local memory due to a speculative PCI read operation

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12.2.3 Guaranteeing Minimum PCI Access Latency to Local Memory

On the MPC8240, enabling snooping by clearing PICR2[NOSNOOP_EN] can improve the PCI access latency to local memory by eliminating pipelined processor transactions that have a priority 1.5 in Table 12-2. However, this can also degrade overall system performance by causing all transactions to be snooped on the internal processor bus.

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Chapter 13
Error Handling

The MPC8240 provides error detection and reporting on the three primary interfaces (processor core, memory, and PCI). This chapter describes how the MPC8240 handles different error conditions. Note that interrupts routed to the embedded programmable interrupt controller (EPIC) are detected and reported by the EPIC and are not considered as part of the internal error handling of the MPC8240 as described in this chapter. See Chapter 11, "Embedded Programmable Interrupt Controller (EPIC) Unit," for more information about the EPIC unit.

13.1 Overview

Errors detected by the MPC8240 are reported to the processor core by asserting an internal machine check signal ($\overline{mcp}$). The state of the internal machine check signal is externally driven on the $\overline{\text{MCP}}$ output signal. The system error ($\overline{\text{SERR}}$) and parity error ($\overline{\text{PERR}}$) signals are used to report errors on and to the PCI bus. The MPC8240 provides the NMI signal for ISA bridges to report errors on the ISA bus. The MPC8240 internally synchronizes any asynchronous error signals.

The PCI command, PCI status, and the error handling registers enable or disable the reporting and detection of specific errors. These registers are described in Chapter 4, "Configuration Registers."

The MPC8240 detects illegal transfer types from the processor, illegal Flash write transactions, PCI address and data parity errors, accesses to memory addresses out of the range of physical memory, memory parity errors, memory refresh overflow errors, ECC errors, PCI master-abort cycles, and PCI received target-abort errors.

The MPC8240 latches the address and type of transaction that caused the error in the error status registers to assist diagnostic and error handling software. Note that not all transactions can be captured. See Section 4.8.2, "Error Enabling and Detection Registers," for more information. Section 2.2.5, "System Control and Power Management Signals," contains the signal definitions for the interrupt signals.

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13.1.1 Error Handling Block Diagram

Figure 13-1 provides the internal error management block diagram.

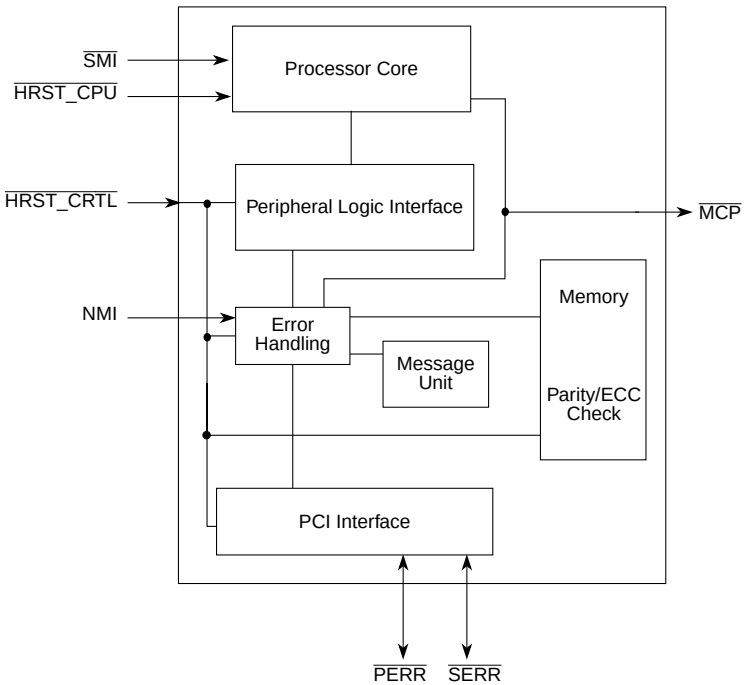

Figure 13-1. Internal Error Management Block Diagram

13.1.2 Priority of Externally Generated Errors and Exceptions

Many of the errors detected in the MPC8240 cause exceptions to be taken by the processor core. Table 13-1 describes the relative error priorities.The processor exception generated by each of these conditions is described in Section 5.5, “Exception Model.”

Table 13-1. MPC8240 Error Priorities

Priority	Exception	Cause
0	Hard reset	Hard reset (required on power-on); HRST_CRTL and HRST_CPU asserted (must always be asserted together)
1	Machine check	Processor transaction error or Flash write error
2	Machine check	PCI address parity error (SERR) or PCI data parity error (PERR) when the MPC8240 is acting as the PCI target
3	Machine check	Memory select error, memory data read parity error, memory refresh overflow, or ECC error

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Table 13-1. MPC8240 Error Priorities (Continued)

Priority	Exception	Cause
4	Machine check	PCI address parity error ($\overline{\text{SERR}}$) or PCI data parity error ($\overline{\text{PERR}}$) when the MPC8240 is acting as the PCI master, PCI master-abort, or received PCI target-abort
5	Machine check	NMI (nonmaskable interrupt), inbound doorbell register machine check (IDBR[MC]), or inbound message register overflow flags (IMISR[OFO] and IMISR[IPO])

Note that for priority 1 through 5, the exception is the same. The machine check exception and the priority are related to additional error information provided by the MPC8240 (for example, the address provided in the Processor/PCI error address register).

13.2 Exceptions and Error Signals

Although Section 2.2.5, “System Control and Power Management Signals,” contains the signal definitions for the exception and error signals, this section describes the interactions between system components when an exception or error signal is asserted.

13.2.1 System Reset

The system reset exception is an asynchronous, nonmaskable interrupt that occurs when the hard reset input signals are ($\overline{\text{HRST\_CPU}}$ and $\overline{\text{HRST\_CTRL}}$ are both) asserted (required at power-on). The MPC8240 has two hard reset input signals, $\overline{\text{HRST\_CPU}}$ and $\overline{\text{HRST\_CRTL}}$, and they must be asserted and negated simultaneously.

When a system reset is recognized ($\overline{\text{HRST\_CPU}}$ and $\overline{\text{HRST\_CTRL}}$ are both asserted), the MPC8240 aborts all current internal and external transactions, releases all bidirectional I/O signals to a high-impedance state, ignores the input signals (except for PCI_SYNC_IN and the configuration signals described in Section 2.4, “Configuration Signals Sampled at Reset”), and drives most of the output signals to an inactive state. Table 2-2 shows the states of the output-only signals during system reset. The MPC8240 then initializes its internal logic.

For proper initialization, the assertion of $\overline{\text{HRST\_CPU}}$ and $\overline{\text{HRST\_CTRL}}$ must satisfy the minimum active pulse width requirements given in the *MPC8240 Hardware Specification*.

Note that the latches dedicated to JTAG functions are not initialized during system reset. The IEEE 1149.1 standard prohibits the device reset from resetting the JTAG logic. The JTAG reset ($\overline{\text{TRST}}$) signal is required to reset the dedicated JTAG logic during power-on.

13.2.2 Processor Core Error Signal ($\overline{mcp}$)

The MPC8240 provides an internal machine check signal ($\overline{mcp}$) to the processor core for error reporting.

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The internal machine check signal indicates to the processor that a nonrecoverable error has occurred during system operation. The state of *mcp* is provided externally on the MCP output signal. The assertion of *mcp* depends upon whether the error handling registers of the MPC8240 are set to report the specific error. The programmable parameter PICR1[MCP_EN] is used to enable or disable the assertion of *mcp* by the MPC8240 for all error conditions. Assertion of *mcp* causes the processor core to take a machine check exception conditionally or enter the checkstop state based on the value of the processor's MSR[ME] bit.

The machine check signal may be asserted to the processor core on any cycle. Whether the current transaction is aborted depends upon the software configuration.

The MPC8240 holds *mcp* asserted until the processor core has taken the exception. The MPC8240 decodes a machine check acknowledge cycle by detecting processor reads from the two possible machine check exception addresses at 0x0000_0200–0x0000_0207 and 0xFFF0_0200–0xFFF0_0207, and negates *mcp*. Note that if the MPC8240 is configured for remote ROM (that is, ROM space is located in the PCI memory space), then a processor read from 0xFFF0_0200 will not negate the *mcp* signal. In this case, the machine check exception handler must perform a dummy read from 0x0000_0200 to cause the negation of *mcp*.

13.2.3 PCI Bus Error Signals

The MPC8240 uses three error signals to interact with the PCI bus—SERR, PERR, and NMI.

13.2.3.1 System Error (SERR)

The SERR signal is used to report PCI system errors—PCI address parity error, PCI data parity error on a special-cycle command, target-abort, or any other error where the result is potentially catastrophic. The SERR signal is also asserted for master-abort, except for PCI configuration accesses or special-cycle transactions.

The agent responsible for driving AD[31–0] on a given PCI bus phase is responsible for driving even parity one PCI clock cycle later on the PAR signal. That is, the number of 1s on AD[31–0], C/BE[3–0], and PAR equals an even number.

The SERR signal is driven for a single PCI clock cycle by the agent that is reporting the error. The target agent is not allowed to terminate with retry or disconnect if SERR is activated due to an address parity error.

Bit 8 of the PCI command register controls whether the MPC8240 asserts SERR upon detecting any PCI system error. Whenever the MPC8240 asserts SERR to report a system error on the PCI bus, bit 14 of the PCI status register is set.

Bit 7 of ErrEnR1 enables the reporting (via *mcp*, if enabled) of SERR assertion by an external agent on the PCI bus. If ErrEnR1[7] = 1 with MPC8240 acting as the initiator, and

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an external PCI agent asserts $\overline{\text{SERR}}$ two clock cycles after the address phase, the error is recorded in bit 7 of ErrDR1 and a machine check is generated to the processor core.

13.2.3.2 Parity Error ($\overline{\text{PERR}}$)

The $\overline{\text{PERR}}$ signal is used to report PCI data parity errors during all PCI transactions except for PCI special-cycle command transactions. The agent responsible for driving AD[31–0] on a given PCI bus phase is responsible for driving even parity one PCI clock cycle later on the PAR signal. That is, the number of 1s on AD[31–0], $\overline{\text{C/BE}}$[3–0], and PAR equals an even number.

Two PCI clock cycles after the data phase for which a data parity error is detected, the $\overline{\text{PERR}}$ signal must be asserted by the agent receiving the data. Only the master may report a read data parity error; and only the selected target may report a write data parity error.

Bit 6 of the PCI command register decides whether the MPC8240 ignores $\overline{\text{PERR}}$. Bit 15 and bit 8 of the PCI status register are used to report when the MPC8240 has detected or reported a data parity error.

13.2.3.3 Nonmaskable Interrupt (NMI)

The NMI signal is, effectively, a PCI sideband signal between the PCI-to-ISA bridge and the MPC8240. The NMI signal is usually driven by the PCI-to-ISA bridge to report any nonrecoverable error detected on the ISA bus (normally, through the $\overline{\text{IOCHCK}}$ signal on the ISA bus). The name nonmaskable interrupt is misleading due to its history in ISA bus designs. The NMI signal should be connected to GND if it is not used. If PICR1[MCP_EN] is set, the MPC8240 reports the NMI error to the processor core by asserting $\overline{mcp}$.

13.3 Error Reporting

Error detection on the MPC8240 is designed to log the occurrence of an error and also log information related to the error condition. The individual error detection bits are contained in the PCI status register, error detection register 1 (ErrDR1), error detection register 2 (ErrDR2), and the inbound message interrupt status register (IMISR). These bits indicate which error has been detected. (The error detection bits are specifically bits 15, 13, and 12 in the PCI status register, bits 7–4 and 2–0 in ErrDR1, bits 5–3 and 0 in ErrDR2, and bits 8, 7, and 4 in the IMISR.)

The intent of error reporting is to log the information pertaining to the first error that occurs and prevent additional errors from being reported until the first error is acknowledged and cleared. For additional errors to be reported, all error detection bits must be cleared. When an error detection bit is set, the MPC8240 does not report additional errors until all of the error detection bits are cleared. Note that more than one of the error detection bits can be set if simultaneous errors are detected. Therefore, software must check whether more than one bit is set before trying to determine information about the error.

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The processor/PCI error address register, the processor bus error status register, and the PCI bus error status register together with ErrDR1[3] (processor/PCI cycle) and ErrDR2[7] (invalid error address) provide additional information about a detected error condition. When an error is detected, the associated information is latched inside these registers until all error detection bits are cleared. Subsequent errors set the appropriate error detection bits, but the bus error status and error address registers retain the information for the initial error until all error detection bits are cleared.

As described in Section 13.2.2, “Processor Core Error Signal (mcp),” the MPC8240 asserts $\overline{mcp}$ to the processor core when an enabled error condition has occurred during system operation. The assertion of $\overline{mcp}$ depends upon whether the error handling registers of the MPC8240 are set to report the specific error. Once asserted, the MPC8240 continues to assert $\overline{mcp}$ until the MPC8240 decodes a read from the processor to the machine check exception vector (0xnnn0_0200). When it decodes a processor read from the machine check exception vector, the MPC8240 negates $\overline{mcp}$. Note that if the system ROM space is located on the PCI bus, then a processor read from 0xFFF0_0200 will not negate the $\overline{mcp}$ signal. In this case, the machine check exception handler must perform a dummy read from 0x0000_0200 to cause the negation of $\overline{mcp}$.

Until all the error detection bits are cleared, the MPC8240 does not report subsequent errors by reasserting $\overline{mcp}$.

Certain events in the inbound portion of the message unit can cause the assertion of $\overline{mcp}$. These events can mask (or be masked by) other errors until the machine check exception handler clears them.

In addition to the error detection bits, the MPC8240 reports the assertion of NMI to the processor core by asserting $\overline{mcp}$ (if enabled). Note that NMI assertion is not recorded in the MPC8240's error detection bits. Reporting NMI assertion (by $\overline{mcp}$) can be masked by any error detection bits that are set.

13.3.1 Processor Interface Errors

The processor interface of the MPC8240 detects unsupported processor bus transaction errors, Flash write errors, and write parity errors. In these cases, both ErrDR1[3] and ErrDR2[7] are cleared, indicating that the error is due to a processor transaction and the address in the processor/PCI error address register is valid.Internally, the MPC8240 asserts transfer acknowledge (provided PICR1[10] = 0) to terminate the data tenure.

13.3.1.1 Processor Transaction Error

When a processor transaction error occurs, ErrDR1[1–0] is set to reflect the error type. Unsupported processor bus transactions include writes to the PCI interrupt-acknowledge space (0xBFFF_FFFn using address map A or 0xFEFn_nnnn using address map B) and attempts to execute the graphic read or graphic write instructions (**eciwx** or **ecowx**).

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13.3.1.2 Flash Write Error

The MPC8240 allows processor writes to the local ROM space when PICR1[FLASH_WR_EN] is set and PICR2[FLASH_WR_LOCKOUT] is cleared. Otherwise, any processor write transaction to the local ROM space results in a Flash write error. Attempts to write to local ROM space from a PCI master or the DMA controller also cause Flash write errors. When a Flash write error occurs, ErrDR2[0] is set.

The ROM/Flash interface on the MPC8240 accommodates only single-beat, datapath-sized (8-, 32-, or 64-bit depending on the configuration) writes to Flash memory. This requires that all writes to system ROM space must be either caching-inhibited, or caching-allowed/write-through. Any burst write to ROM space causes a Flash write error.

Software must partition larger data into individual datapath-sized (8-, 32-, or 64-bit) write operations.Note that an attempt to write to Flash with a data size larger than the data path size (for example, a 32-bit write to 8-bit Flash) does not cause a Flash write error, but the data in the unused byte lanes is ignored.

13.3.1.3 Processor Write Parity Error

When both ErrEnR2[2] and MCCR2[WRITE_PAR_CHK] are set, the MPC8240 checks processor parity on memory write cycles with the stipulations described in Table 13-2.

Table 13-2. Processor Write Parity Checking

Memory Type	Memory Error Protocol[1]	Processor Write Parity Checking
SDRAM	None	Not supported
	Parity	Yes
	RMW parity	Not supported
	ECC	Yes
FPM/EDO DRAM	None	Not supported
	Parity	Yes
	RMW parity	Not supported
	ECC	Not supported

1 See Table 6-9 or Table 6-20 for specific bit settings.

When a processor write parity error occurs, ErrDR2[2] is set. Note that the MPC8240 does not check parity for write transactions to PCI or the local ROM address space.

13.3.2 Memory Interface Errors

The memory interface of the MPC8240 detects read parity, ECC, memory select, and refresh overflow errors. The MPC8240 detects parity errors on the data bus during memory (DRAM/EDO/SDRAM) read cycles. The memory controller can detect single-bit and multi-bit errors for local memory read transactions. Since the ECC logic corrects single-bit errors, they are reported only when the number of errors in the ECC single-bit error counter

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register equals the threshold value in the ECC single-bit error trigger register. A memory select error occurs when a local memory transaction address falls outside of the physical memory boundaries as programmed in the memory boundary registers. A refresh overflow error occurs when no refresh transaction occurs within the equivalent of 16 refresh cycles.

In all cases, if the memory transaction is initiated by a PCI master, ErrDR1[3] is set; if the memory transaction is initiated by the processor core, ErrDR1[3] is cleared.

ErrDR2[7] is cleared to indicate that the error address in the processor/PCI error address register is valid. If the ECC single-bit error trigger threshold is reached, then the error address indicates the address of the most recent ECC single-bit error. Note that when a parity or ECC error occurs on the last beat of a transaction and another transaction to the same page has started, the MPC8240 cannot provide the error address and the corresponding bus status. In these cases, ErrDR2[7] is set to indicate that the error address in the processor/PCI error address register is not valid. The MPC8240 cannot provide the error address and the bus status for refresh overflow errors, so ErrDR2[7] is set for these errors as well.

If the transaction is initiated by the processor core or by a PCI master with bit 6 of the PCI command register cleared, the error status information is latched, but the transaction continues and terminates normally.

13.3.2.1 Memory Read Data Parity Error

When MCCR1[PCKEN] is set, the MPC8240 checks memory parity on every memory read cycle and generates the parity on every memory write cycle that emanates from the MPC8240. When a read parity error occurs, ErrDR1[2] is set.

The MPC8240 does not check parity for transactions in the local ROM address space. Note that the processor should not check parity for local ROM space transactions because the parity data will be incorrect for these accesses.

13.3.2.2 Memory ECC Error

The MPC8240 can be configured to perform an ECC check on every memory read cycle; it also generates the ECC check data on every memory write cycle. SDRAM systems use the in-line ECC configuration shown in Table 6-9 on page 6-14; FPM and EDO DRAM systems use the ECC configuration shown in Table 6-20 on page 6-54.

When a single-bit ECC error occurs, the ECC single-bit error counter register is incremented by one, and its value is compared to the value in the ECC single-bit error trigger register. If the values are equal, ErrDR1[2] is set. In addition to single-bit errors, the MPC8240 detects all 2-bit errors, all errors within a nibble (one-half byte), and any other multi-bit error that does not alias to either a single-bit error or no error. When a multi-bit ECC error occurs, ErrDR2[3] is set.

Write parity errors are reported in ErrDR1[2] (memory read parity error/ECC single-bit error exceeded). Read parity and multiple-bit ECC errors are reported in ErrDR2[3] (ECC multi-bit error).

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13.3.2.3 Memory Select Error

A memory select error occurs when the address for a local memory transaction falls outside of the programmed boundaries of physical memory. When a memory select error occurs, ErrDR1[5] is set. If a write transaction causes a memory select error, the write data is simply ignored. If a read transaction causes the memory select error, the MPC8240 returns all 1s (0xFFFF_FFFF). No $\overline{RAS}/\overline{CS}$ signals are asserted in either case.

13.3.2.4 Memory Refresh Overflow Error

When there are no refresh transactions for a period equal to 16 refresh cycles, the MPC8240 reports the error as a refresh overflow. When the MPC8240 detects a refresh overflow, ErrDR1[3] is set. See Section 6.2.12, “SDRAM Refresh,” and Section 6.3.10, “FPM or EDO DRAM Refresh,” for more information about memory refresh.

13.3.3 PCI Interface Errors

The MPC8240 supports the error detection and reporting mechanism as specified in the *PCI Local Bus Specification*, Revision 2.1. The MPC8240 keeps error information and sets the appropriate error flags when a PCI error occurs (provided the corresponding enable bit is set), independent of whether the PCI command register is programmed to respond to or detect the specific error.

In cases of PCI errors, ErrDR1[3] is set to indicate that the error is due to a PCI transaction. In most cases, ErrDR2[7] is cleared to indicate that the error address in the processor/PCI error address register is valid. In these cases, the error address is the address as seen by the PCI bus, not the processor core’s physical address.

If NMI is asserted, the MPC8240 cannot provide the error address and the corresponding bus error status. In such cases, ErrDR2[7] is set to indicate that the error address in the processor/PCI error address register is not valid.

13.3.3.1 PCI Address Parity Error

Bit 6 of the PCI command register controls whether the MPC8240takes action when it detects an address or data parity error has occurred. When the MPC8240 detects an address or data parity error, it sets bit 15 in the PCI status register, regardless of the settings in the PCI command register. Bit 7 of ErrEnR2 enables the reporting of PCI address parity errors to the processor core (via $\overline{mcp}$, if enabled).

Bit 8 of the PCI command register controls whether the MPC8240 asserts $\overline{SERR}$ upon detecting any PCI system error including an address parity error. Whenever the MPC8240 asserts $\overline{SERR}$ to report a system error on the PCI bus, bit 14 of the PCI status register is set.

Bit 7 of ErrEnR1 enables the reporting (via $\overline{mcp}$, if enabled) of $\overline{SERR}$ assertion by an external agent on the PCI bus. If ErrEnR1[7] = 1 and the MPC8240 is acting as the initiator and an external PCI agent asserts $\overline{SERR}$ two clock cycles after the address phase, the error is recorded in bit 7 of ErrDR1 and a machine check is generated to the processor core.

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13.3.3.2 PCI Data Parity Error

If the MPC8240 is acting as a PCI master and a data parity error occurs, the MPC8240 sets bit 15 of the PCI status register. This is independent of the settings in the PCI command register.

If the PCI command register of the MPC8240 is programmed to respond to parity errors (bit 6 of the PCI command register is set) and a data parity error is detected or signaled during a PCI bus transaction, the MPC8240 sets the appropriate bits in the PCI status register (bit 15 is set, and possibly bit 8 is set, as described in the following paragraphs).

If a data parity error is detected by the MPC8240 acting as the master (for example, during a processor-read-from-PCI transaction) and bit 6 of the PCI command register is set, the MPC8240 reports the error to the PCI target by asserting $\overline{\text{PERR}}$ and setting bit 8 of the status register; and tries to complete the transaction, if possible. Also, if PICR1[MCP_EN] is set, the MPC8240 asserts $\overline{mcp}$ to report the error to the processor core. These actions also occur if the MPC8240 is the master and detects the assertion of $\overline{\text{PERR}}$ by the target (for a write).

If the MPC8240 is acting as a PCI target when the data parity error occurs (on a write), the MPC8240 asserts $\overline{\text{PERR}}$ and sets ErrDR1[6] (PCI target $\overline{\text{PERR}}$). If the data has been transferred, the MPC8240 completes the operation but discards the data. Also, if PICR1[MCP_EN] is set, the MPC8240 asserts $\overline{mcp}$ to report the error to the processor core. If the master asserts $\overline{\text{PERR}}$ during a memory read, the address of the transfer is logged in the error address register and $\overline{mcp}$ is asserted (if enabled).

13.3.3.3 PCI Master-Abort Transaction Termination

If the MPC8240, acting as a master, initiates a PCI bus transaction (excluding special-cycle transactions), but there is no response from any PCI agent ($\overline{\text{DEVSEL}}$ has not been asserted within five PCI bus clocks from the start of the address phase), the MPC8240 terminates the transaction with a master-abort and sets the master-abort flag (bit 13) in the PCI status register. Special-cycle transactions are normally terminated with a master-abort, but these terminations do not set the master-abort flag in the PCI status register.

If ErrEnR1[1] is set and the MPC8240 terminates a transaction with a master-abort, the MPC8240 reports the error to the processor core by asserting $\overline{mcp}$ (provided PICR1[MCP_EN] is set).

13.3.3.4 Received PCI Target-Abort Error

If a PCI transaction initiated by the MPC8240 is terminated by target-abort, the received target-abort flag (bit 12) of the PCI status register is set. If ErrEnR2[1] and PICR1[MCP_EN] are both set and the MPC8240 receives a target-abort, the MPC8240 reports the error to the processor core by asserting $\overline{mcp}$ (provided PICR1[MCP_EN] is set).

Note that any data transferred in a target-abort transaction may be corrupt.

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13.3.3.5 NMI (Nonmaskable Interrupt)

If PICR1[MCP_EN] is set and a PCI agent asserts the NMI signal to the MPC8240, the MPC8240 reports the error to the processor core by asserting *mcp* provided PICR1[MCP_EN] is set.

When the NMI signal is asserted, no error flags are set in the status registers of the MPC8240. The agent that drives NMI should provide the error flag for the system and the mechanism to reset that error flag. The NMI signal should then remain asserted until the error flag is cleared.

13.3.4 Message Unit Error Events

The inbound portion of the message unit can cause the assertion of *mcp* by a software programmable flag. There are also two overflow events on the inbound message queues that can cause the assertion of *mcp*. See Chapter 9, "Message Unit (with I2O)," for more information on the message unit.

The MC bit in the IDBR allows a PCI master to generate a machine check interrupt (*mcp*) to the processor core.

The IMISR contains the interrupt status of the I_2O, doorbell, and message register events. These events are generated by PCI masters and are routed to the processor core from the message unit with the internal *int* or *mcp* signals. The specific bits in the IMISR that can cause *mcp* to be asserted are the outbound free_list overflow condition (OFO) and the inbound post_list overflow condition (IPO). In addition, the doorbell machine check condition IMISR[DMC] provides an indication that the IDBR[MC] bit has been set by a PCI master.

The processor core interrupt handling software must service these interrupts and clear the interrupt bits. Software attempting to determine the source of the interrupts should always perform a logical AND between the IMISR bits and their corresponding mask bits in the IMIMR.

13.4 Exception Latencies

Latencies for taking various exceptions depend on the state of the MPC8240 when the conditions to produce an exception occur. The minimum latency is one cycle, in which case the exception is signaled in the cycle after the exception condition occurs.

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Chapter 14
Power Management

A key feature of the MPC8240 and its predecessor, the MPC603e microprocessor, is that they are designed for low-power operation. The MPC8240 provides both automatic and program-controllable power reduction modes for progressive reduction of power consumption. This chapter describes the support features provided by the MPC8240 for power management of both the processor core and the peripheral logic.

14.1 Overview

The MPC8240 has explicit power management features for both the processor core and the peripheral logic, both of which are described in this chapter. Note that the design of the MPC8240 is fully static, allowing the internal logic states to be preserved during power management. The MPC8240 implementation offers the following enhancements to the original MPC603e family:

- Lower-power design
- 2.5-volt core and 3.3-volt I/O

Because operating systems service I/O requests by system calls to the device drivers, the device drivers must be modified for power management. When a device driver is called to reduce the power of a device, it needs to be able to check the power state of the device, save the device configuration parameters, and put the device into a power-saving mode. Furthermore, every time the device driver is called it needs to check the power status of the device; and restore the device to the full-on state, if the device is in a power-saving mode.

14.2 Processor Core Power Management

The processor core has various types of power management features. Dynamic power management occurs automatically (if enabled), depending on the activity of the execution units. The programmable doze, nap, and sleep modes provide further power savings. The power management features in the processor core are very similar to that in the MPC603e device.

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14.2.1 Dynamic Power Management

Dynamic power management (DPM) automatically powers up and down the individual execution units of the MPC8240 processor core, based upon the contents of the instruction stream. For example, if no floating-point instructions are being executed, the floating-point unit is automatically powered down. Power is not actually removed from the execution unit; instead, each execution unit has an independent clock input that is automatically controlled on a clock-by-clock basis. Because CMOS circuits consume negligible power when they are not switching, stopping the clock to an execution unit effectively eliminates its power consumption. The operation of DPM is transparent to software or any external hardware. Dynamic power management is enabled by setting bit 11 in HID0 following a hard reset sequence.

14.2.2 Programmable Power Modes on Processor Core

The peripheral logic block can wake up the processor from a low power state through the internal asynchronous interrupt ($\overline{int}$) signal (generated by the EPIC unit), which transfers program flow to the interrupt handler code. The appropriate mode then is set by the software. The MPC8240 provides a second interrupt signal and interrupt vector for power management—the system management interrupt ($\overline{SMI}$). The MPC8240 also contains a decrementer timer that allows it to enter the nap or doze mode for a specified period and then return to full power operation through the decrementer interrupt exception.

The four processor power modes are selectable by setting the appropriate control bits in the MSR and HID0 registers. The following is a brief description of the four power modes:

- Processor full-power—This is the default power state of the MPC8240. The MPC8240 is fully powered and the internal functional units are operating at the full processor clock speed. If the dynamic power management mode is enabled, functional units that are idle automatically enter a low-power state without affecting performance, software execution, or external hardware.
- Processor doze—All the functional units of the processor core are disabled except for the time base/decrementer registers and the bus snooping logic. When the processor is in doze mode, an asynchronous interrupt (signalled by the assertion of $\overline{int}$), a system management interrupt, a decrementer exception, a hard or soft reset, or any machine check exception brings the MPC8240 into the full-power state. The MPC8240 in doze mode maintains the PLL in a fully powered state and is locked to the internal *sys_logic_clk* signal so a transition to the full-power state occurs within four processor clock cycles.
- Processor nap—The nap mode further reduces power consumption by disabling bus snooping by the processor, leaving only the time base register and the PLL in a powered state. The MPC8240 returns to the full-power state upon receipt of an interrupt (signalled by the assertion of $\overline{int}$), a system management interrupt (signalled by the assertion of $\overline{SMI}$), a decrementer exception, a hard or soft reset, or

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any machine check exception. Also, negation of $\overline{\text{QACK}}$ (controlled by the peripheral logic block) causes the processor core to wake up from nap mode. A return to full-power state from a nap state occurs within four processor clock cycles

- Processor sleep—Sleep mode reduces power consumption to a minimum by disabling all internal functional units, after which external logic can disable the PLL and the internal *sys_logic_clk* signal. The MPC8240 returns to the full-power state from sleep mode upon receipt of an interrupt (signalled by the assertion of $\overline{int}$), a system management interrupt, a hard or soft reset, or any machine check exception. Also, negation of $\overline{\text{QACK}}$ (controlled by the peripheral logic block) causes the processor core to wake up from sleep mode.

  The external system logic must enable the processor PLL and the internal *sys_logic_clk* signal before any of the wake-up events occur. Refer to Section 14.3.2.4.2, “Disabling the PLL during Sleep Mode,” for more information on how the PLLs are locked and Section 2.3, “Clocking,” for more information on the clock signals of the MPC8240.

Note that the processor core cannot switch from one power management mode to another without first returning to full-on mode. Table 14-1 summarizes the four power states for the processor.

Table 14-1. Programmable Processor Power Modes

PM Mode	Functioning Units	Activation Method	Full-Power Wake Up Method
Full power	All units active	—	—
Full power (with DPM)	Requested logic by demand	By instruction dispatch	—
Doze	Bus snooping Data cache as needed Decrementer timer	Controlled by software (write to HID0)	External asynchronous exceptions (assertion of $\overline{\text{SMI}}$ or $\overline{\text{int}}$) Decrementer exception Hard or soft reset Machine check exception ($\overline{\text{mcp}}$)
Nap	Decrementer timer	Controlled by software (write to HID0) and qualified with $\overline{\text{QACK}}$ from peripheral logic	External asynchronous exceptions (assertion of $\overline{\text{SMI}}$, or $\overline{\text{int}}$) Decrementer exception Negation of $\overline{\text{QACK}}$ by peripheral logic Hard or soft reset Machine check exception ($\overline{\text{mcp}}$)
Sleep	None	Controlled by software (write to HID0) and qualified with $\overline{\text{QACK}}$ from peripheral logic	External asynchronous exceptions (assertion of $\overline{\text{SMI}}$, or $\overline{\text{int}}$) Negation of $\overline{\text{QACK}}$ by peripheral logic Hard or soft reset Machine check exception ($\overline{\text{mcp}}$)

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14.2.3 Processor Power Management Modes—Details

The following sections describe the characteristics of the MPC8240 power management modes, the requirements for entering and exiting the various modes, and the system capabilities provided by the processor core while the power management modes are active.

For the processor to enter nap or sleep mode, the software first programs the processor for one of those modes. Then the peripheral logic must be programmed for nap or sleep mode. When the peripheral logic is ready to nap or sleep, it signals that the processor can enter the nap or sleep mode and asserts the $\overline{\text{QACK}}$ output signal. If the peripheral logic wakes from nap or sleep (causing $\overline{\text{QACK}}$ to negate), the processor also wakes from nap or sleep mode.

14.2.3.1 Full-Power Mode with DPM Disabled

Full-power mode with DPM disabled power mode is selected when the DPM enable bit (bit 11) in HID0 is cleared. The following characteristics apply:

- Default state following assertion of $\overline{\text{HRST\_CPU}}$ and $\overline{\text{HRST\_CTRL}}$
- All functional units are operating at full processor speed at all times

14.2.3.2 Full-Power Mode with DPM Enabled

Full-power mode with DPM enabled (HID0[11] = 1) provides on-chip power management without affecting the functionality or performance of the MPC8240 as follows:

- Required functional units are operating at full processor speed
- Functional units are clocked only when needed
- No software or hardware intervention required after mode is set
- Software/hardware and performance transparent

14.2.3.3 Processor Doze Mode

Doze mode disables most functional units but maintains cache coherency by enabling bus snooping. A snoop hit causes the processor core to enable the data cache, copy the data back to memory, disable the cache, and fully return to the doze state.

Doze mode is characterized by the following features:

- Most functional units disabled
- Bus snooping and time base/decrementer still enabled
- PLL running and locked to the internal *sys_logic_clk* signal

To enter the doze mode, the following conditions must occur:

- Set doze bit (HID0[8] = 1).
- The MPC8240 enters doze mode after several processor clocks.

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To return to full-power mode the following conditions must occur:

- Internal $\overline{int}$ or $\overline{mcp}$ signals asserted to the processor by the peripheral logic block, NMI asserted, $\overline{SMI}$ asserted, or decrementer exception
- Hard reset or soft reset
- Transition to full-power state occurs within four processor cycles.

14.2.3.4 Processor Nap Mode

The nap mode disables the processor core except for the processor phase-locked loop (PLL) and the time base/decrementer. The time base can be used to restore the processor core to full-on state after a specified period.

Because bus snooping is disabled for nap and sleep mode, the peripheral logic block delays the processor from entering into nap mode until all the peripheral logic internal buffers are flushed and there is no outstanding transaction. Also, software must ensure that no PCI master accesses main memory, unless software can guarantee that none of the accesses would correspond to a modified line in the L1 cache.

When the peripheral logic block has ensured that snooping is no longer necessary, it allows the processor to enter the nap (or sleep) mode and it causes the assertion of the MPC8240 $\overline{QACK}$ output signal for the duration of the nap mode period.

Nap mode is characterized by the following features:

- Time base/decrementer still enabled
- Most functional units disabled (including bus snooping)
- PLL running and locked to the internal *sys_logic_clk* signal

To enter the nap mode, the following conditions must occur:

- Set nap bit (HID0[9] = 1).
- Processor asserts internal request for nap or sleep mode to the peripheral logic.
- Peripheral logic must be programmed for nap or sleep mode.
- MPC8240 asserts quiesce acknowledge ($\overline{QACK}$) output signal after flushing the internal buffers in peripheral logic block.
- Processor core enters nap mode after several processor clocks. (Peripheral logic also enters the nap or sleep mode.)

To return to full-power mode the following conditions must occur:

- Internal $\overline{int}$ or $\overline{mcp}$ signals asserted or $\overline{QACK}$ negated by the peripheral logic block, $\overline{SMI}$ asserted, or decrementer exception
- Hard reset or soft reset
- Transition to full-power occurs within four processor cycles.

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14.2.3.5 Processor Sleep Mode

Sleep mode consumes the least amount of power of the four modes since all functional units are disabled. To conserve the maximum amount of power, the processor PLL and the internal *sys_logic_clk* signals can be disabled to the processor. Due to the fully static design of the MPC8240, internal processor state is preserved when no internal clock is present. Because the time base and decrementer are disabled while the processor is in sleep mode, the time base contents must be updated from an external time base following sleep mode if accurate time-of-day maintenance is required.

As in nap mode, the peripheral logic block delays the processor from entering into sleep mode until all the internal buffers are flushed and there is no outstanding transaction. When the peripheral logic block has ensured that snooping is no longer necessary, it allows the processor core to enter the sleep mode and it asserts the $\overline{\text{QACK}}$ output signal for the duration of the sleep mode period.

Sleep mode is characterized by the following features:

- All processor functional units disabled (including bus snooping and time base)
- All nonessential input receivers disabled
- Internal clock regenerators disabled
- Processor PLL and the internal *sys_logic_clk* signal can be disabled.

To enter sleep mode the following conditions must occur:

- Set sleep bit (HID0[10] = 1).
- Processor asserts internal request for nap or sleep mode to the peripheral logic.
- Peripheral logic must be programmed for nap or sleep mode.
- MPC8240 asserts quiesce acknowledge ($\overline{\text{QACK}}$) output signal after flushing the internal buffers of peripheral logic block.
- Processor core enters sleep mode after several processor clocks. (Peripheral logic also enters the nap or sleep mode.)

To return to full-power mode the following conditions must occur:

- Internal $\overline{int}$ or $\overline{mcp}$ signals asserted or $\overline{\text{QACK}}$ negated by the peripheral logic block, NMI asserted, or $\overline{\text{SMI}}$ asserted
- Hard reset or soft reset

14.2.4 Power Management Software Considerations

Because the processor core is a dual-issue processor with out-of-order execution capability, care must be taken in how the processor power management modes are entered. Furthermore, nap and sleep modes require all outstanding bus operations to be completed

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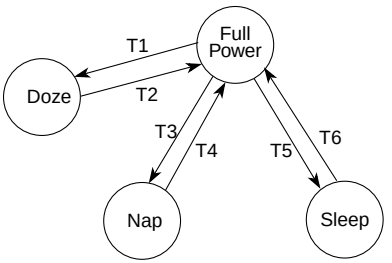
before the processor power management mode is entered. Section 14.4, “Example Code Sequence for Entering Processor and Peripheral Logic Sleep Modes,” provides an example software sequence for putting the processor core into sleep mode.

14.3 Peripheral Logic Power Management

Similar to the power management features of the processor core, the peripheral logic block of the MPC8240 has its own doze, nap and sleep modes. They are described in the following subsections.

The three programmable power saving modes provide different levels of power savings. Doze, nap, and sleep are entered through software by setting the corresponding configuration register bit in the power management control register one (PMCR1). For more information about this register, see Section 4.3.1, “Power Management Configuration Register 1 (PMCR1)—Offset 0x70.” In addition, the PMCR1[PM] global power management bit must be set to 1 to enable any of the power saving modes of the peripheral logic block. Figure 14-1 shows the four power states of the MPC8240 peripheral logic block (three programmable power saving modes plus full-power), and the conditions required for entering and exiting those modes.



T1: PMCR1(DOZE) = 1 & PMCR1(PM) = 1
T2: hard reset, br = 0, PCI address hit, NMI
T3: PMCR1(NAP) = 1 & PMCR1(PM) = 1 & [proc_NAP (or SLEEP) request]
T4: hard reset, br = 0, PCI address hit, NMI
T5: PMCR1(SLEEP) = 1 & PMCR1(PM) = 1 & [proc_NAP (or SLEEP) request]
T6: hard reset, br = 0, NMI

Figure 14-1. MPC8240 Peripheral Logic Power States

14.3.1 MPC8240 Peripheral Power Mode Transitions

For the peripheral logic to enter into either nap or sleep mode, the processor must have requested to enter either nap or sleep mode. If the processor wakes up from nap or sleep, the peripheral logic also wakes up from nap or sleep.

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In doze, nap, and sleep modes, the peripheral logic always monitors the internal bus request signal from the processor core. When it is asserted, for example due to the occurrence of the decrementer exception, the peripheral logic exits its low power state and goes back to the full-power state to service the request.

The MPC8240 does not support the broadcast of PCI special cycles related to low-power operation. Thus, the PMCR1[NO_NAP_MSG] and PMCR1[NO_SLEEP_MSG] bits must be set by initialization software (they are cleared upon reset) to indicate that the MPC8240 does not broadcast the HALT or sleep message commands on the PCI bus before entering the nap or sleep modes, respectively.

Table 14-2 summarizes the functionality and transition criteria of the peripheral logic block in all power states.

Table 14-2. Peripheral Logic Power Modes Summary

PM Mode	Functioning Units	Activation Method	Full-Power Wake Up Method
Full power	All units active	—	—
Doze	PCI address decoding and bus arbiter System RAM refreshing Processor bus request and NMI monitoring EPIC unit I^2C unit PLL	Controlled by software (write to PMCR1)	PCI access to memory Processor bus request Assertion of NMI[1] Interrupt to EPIC Hard Reset
Nap	PCI address decoding and bus arbiter System RAM refreshing Processor bus request and NMI monitoring EPIC unit I^2C unit PLL	Controlled by software (write to PMCR1) and processor core in nap or sleep mode ($\overline{\text{QREQ}}$ asserted)	PCI access to memory[2] Processor bus request Assertion of NMI[1] Interrupt to EPIC Hard Reset
Sleep	PCI bus arbiter System RAM refreshing (can be disabled) Processor bus request and NMI monitoring EPIC unit I^2C unit PLL (can be disabled)	Controlled by software (write to PMCR1) and processor core in nap or sleep mode ($\overline{\text{QREQ}}$ asserted)	Processor bus request Assertion of NMI[1] Interrupt to EPIC Hard Reset

1 Programmable option based on value of PICR1[MCP_EN] = 1

2 A PCI access to memory in nap mode does not cause $\overline{\text{QACK}}$ to negate; consequently, it does not wake up the processor core, and the processor core won't snoop this access. After servicing the PCI access, the peripheral logic automatically returns to the nap mode.

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14.3.2 Peripheral Power Management Modes

The following sections describe the characteristics of the MPC8240 peripheral power management modes, the requirements for entering and exiting the various modes, and the system capabilities provided by the processor core while the power management modes are active.

14.3.2.1 Peripheral Logic Full Power Mode

The default power state of the MPC8240 is full-power. In this state, the peripheral logic block is fully powered, and the internal functional units are operating at full clock speed.

14.3.2.2 Peripheral Logic Doze Mode

The doze mode is entered when PMCR1[DOZE] and PMCR1[PM] are set and there are no pending operations for the MPC8240. In this power-saving mode, all functional units of the peripheral logic block are disabled except for PCI address decoding, the PCI bus arbiter, system RAM refreshing, processor bus request monitoring, and NMI signal monitoring. Also, the EPIC and I^2C units continue to function.

When the peripheral logic is in the doze state, a PCI transaction referenced to the system memory, a processor bus request, the assertion of NMI (provided PICR1[MCP_EN] = 1), the assertion of $\overline{int}$ from the EPIC unit (due to an interrupt condition into the EPIC unit), or a hard reset brings the peripheral logic out of the doze mode and into the full-power state. Note that other processor exceptions (for example, due to the assertion of the $\overline{SMI}$ signal) cause processor bus cycles which indirectly cause the peripheral logic to wake up from doze mode.

After the request has been serviced, the peripheral logic goes back to the doze state unless PMCR1[DOZE] or PMCR1[PM] has been cleared or there are pending operations to perform.

In doze mode, the PLL is fully operational and locked to PCI_SYNC_IN. The transition to the full-power state occurs within four processor clock cycles. The peripheral logic doze mode operates totally independently from the power saving state of the processor.

14.3.2.3 Peripheral Logic Nap Mode

Further power-saving from doze mode can be guaranteed through the peripheral logic nap mode because the peripheral logic does not enter the nap mode unless the processor core is ready to enter either nap or sleep mode. The peripheral logic nap mode is entered when PMCR1[NAP] and PMCR1[PM] are set and the processor core is ready to nap or sleep. When this occurs, the peripheral logic responds by entering the nap mode and asserting the $\overline{QACK}$ output.

As in peripheral logic doze mode, all peripheral logic functional units are disabled in nap mode except for PCI address decoding, the PCI bus arbiter, system RAM refreshing, processor bus request monitoring, and NMI signal monitoring. Also, the EPIC and I^2C units continue to function.

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When the peripheral logic is in the nap mode, a PCI transaction referenced to the system memory, a processor bus request, the assertion of NMI (provided PICR1[MCP_EN] = 1), the assertion of $\overline{int}$ from the EPIC unit (due to an interrupt condition into the EPIC unit), or a hard reset brings the peripheral logic out of the nap mode and into the full-power state.

If the peripheral logic is awakened by any of these causes except for a PCI transaction, the transaction is serviced, $\overline{QACK}$ negates (causing the processor core to wake up), and PMCR1[PM] is cleared preventing the peripheral logic from automatically re-entering the nap state.

14.3.2.3.1 PCI Transactions During Nap Mode

When the peripheral logic is awakened from the nap state by a PCI-agent initiated transaction, the transaction is serviced, PMCR1[PM] remains set, $\overline{QACK}$ negates and the peripheral logic goes back to the nap state after the transaction has been serviced.

Note that if the MPC8240 is temporarily awakened to service a PCI transaction, the processor core does not respond to any snoop cycles. Software should, therefore, flush the L1 cache before allowing the peripheral logic to enter the nap mode if the system allows PCI accesses to wake up the peripheral logic without guaranteeing that the processor will snoop incoming PCI transactions.

14.3.2.3.2 PLL Operation During Nap Mode

In peripheral logic nap mode, the PLL is fully operational and locked to PCI_SYNC_IN. The transition to the full-power state occurs within four processor clock cycles.

14.3.2.4 Peripheral Logic Sleep Mode

Peripheral logic sleep mode provides further power saving compared to the nap mode. As with nap mode, the peripheral logic does not enter the sleep mode unless the processor core has requested to enter either nap or sleep mode. The sleep mode is entered when PMCR1[SLEEP] and PMCR1[PM] are set and the processor core is ready to nap or sleep. When this occurs, the peripheral logic responds by entering the sleep mode and asserting the $\overline{QACK}$ output. It is important to guarantee that no new PCI transactions occur before PMCR1 is programmed for sleep mode because PCI transactions are not serviced in peripheral logic sleep mode.

When the peripheral logic is in sleep mode, the only functional units operating are the on-chip PCI bus arbiter, system RAM refreshing logic (enabled by PMCR1[LP_REF_EN] for sleep mode), processor bus request monitoring, NMI signal monitoring, the EPIC unit, and the I^2C unit. All other units are shut down.

Similar to nap mode, the following conditions bring the peripheral logic out of the sleep mode and into the full-power state: a processor bus request, the assertion of NMI (provided PICR1[MCP_EN] = 1), the assertion of $\overline{int}$ from the EPIC unit (due to an interrupt condition into the EPIC unit), or a hard reset. PMCR1[PM] is always cleared after the core logic is awakened from the sleep state.

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Note that the PLL_CFG[0:4] pins are sampled when the MPC8240 is waking from sleep mode only if PMCR2[SLEEP] = 1.

14.3.2.4.1 System Memory Refresh during Sleep Mode

When the peripheral logic is in sleep mode, the system memory contents can be maintained either by enabling the memory's self-refresh mode or by having the operating system copy all the memory contents to the hard disk before the peripheral logic enters the sleep state. Alternatively, the MPC8240 refresh logic can continue to perform the refresh function in sleep mode if PMCR1[LP_REF_EN] is set. In this case, MCCR1[SREN] is used to determine whether the refresh is a self refresh (SREN = 1) or a CBR refresh (SREN = 0). If LP_REF_EN is cleared, the refresh operations stop when the MPC8240 enters the sleep mode.

When the MPC8240 is in the sleep state using CBR refresh and keeping the PLL in locked operation, the wake-up latency is comparable to that of nap mode (within four processor clock cycles). However, additional wake-up latency is incurred if the system uses the self-refresh mode and/or turns off the PLL during the sleep state.

14.3.2.4.2 Disabling the PLL during Sleep Mode

When the peripheral logic is in sleep mode, the PLL for the peripheral logic block and the PCI_SYNC_IN input may be disabled by an external power-management controller (PMC) for further power saving. The PLL can be disabled by setting the PLL_CFG(0:4) pins to the PLL bypass mode. See the *MPC8240 Hardware Specification* for detailed information on the PLL modes. Disabling the PLL and/or the PCI_SYNC_IN input during sleep mode should not occur until after the assertion of the $\overline{\text{QACK}}$ output ensuring that the processor is in either nap or sleep mode.

If the peripheral logic PLL is disabled, the external PMC chip should trap all the wake-up events so that it can turn on the PLL (to guarantee the relock time) and/or the PCI_SYNC_IN input before forwarding the wake-up event to the MPC8240. When recovering from sleep mode, the external PMC has to re-enable the PLL and PCI_SYNC_IN first, and then wake up the MPC8240 (using any of the wake-up methods) after 100 µs of PLL relock time.

14.3.2.4.3 SDRAM Paging during Sleep Mode

SDRAM systems that have paging mode enabled must disable paging mode before entering the sleep mode, to avoid memory loss and corruption. After the peripheral logic exits the sleep mode and returns to the full-power state, paging mode can once again be enabled.

14.4 Example Code Sequence for Entering Processor and Peripheral Logic Sleep Modes

The following is a sample code sequence for putting the processor core and peripheral logic into sleep mode. Note that there are no-op instructions used to make the code read and

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execute in program order despite the address munging that causes little endian addressing of instructions already in the cache. If the processor is operating in big-endian mode, these no-op instructions are not needed.

```
*********************************************************************
# First set up peripheral logic power management register
# and the processor core HID0 power management bits
#*********************************************************************
#*********************************************************************
# turn on power management bits
#
        addis       r3, r0, 0x8000       # start building new register number
        ori         r3, r3, 0x0070       # register number 0xf0
        stwbrx      r3, r0, r1           # write this value to CONFIG_ADDR
        sync
        lhbrx       r4, r0, r2           # load r4 from CONFIG_DATA
        addis       r0, r0, 0x0000       # PM=1
        ori         r0, r0, 0xc088       # set bits 15, 14, and 7, 3(sleep)
        or          r4, r4, r0           # set the PM bit
        sync
        sthbrx      r4, r0, r2           #   write   the   modified   data   to
CONFIG_DATA
        sync


#******processor HID and external interrupt initialization******************
#
# set up HID registers for the various PowerPC processors
# hid setup taken from minix's mpxPowerPC.s

        mfspr   r31, pvr         # pvr reg
        srawi    r31, r31, 16
resetTest603:
        cmpi    0, 0, r31, 3
        bne     cr0, endHIDSetup

        addi    r0, r0, 0
        oris    r0, r0, 0x1000   # enable machine check pin EMCP
        oris    r0, r0, 0x0010   # enable dynamic power mgmt DPM
        oris    r0, r0, 0x0020   # enable SLEEP power mode
        ori     r0, r0, 0x8000   # enable the Icache ICE
        ori     r0, r0, 0x4000   # enable the Dcache DCE
        ori     r0, r0, 0x0800   # invalidate Icache ICFI
        ori     r0, r0, 0x0400   # invalidate Dcache DCFI
        mtspr   hid0, r0
        isync


#*********************************************************************
# then when the processor is in a loop, force an SMI interrupt
#*********************************************************************

.orig 0x00001400                        # System management interrupt

# force big endian mode
        stw         r0,0x05f8,r0          # need nop every second inst to make
#code read and execute in program order (up until the isync).
        stw         r0,0x05fc,r0
        mfmsr       r0
        ori         r0,r0,r0
        ori         r0,r0,0x0001            # force big endian LE bit
        ori         r0,r0,r0
        xori        r0,r0,0x0001            # force big endian LE bit
        ori         r0,r0,r0
```


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```
        mtmsr       r0
        ori         r0,r0,r0
        isync
        ori         r0,r0,r0

# save off additional registers to be corrupted
        stw         r20,0x05f4,r0
        mfspr       r21, srr0           # put srr0 in r21
        stw         r21,0x05f0,r0       # put r21 in 0x05f0
        mfspr       r22, srr1           # put srr1 in r22
        stw         r22,0x05ec,r0       # put r22 in 0x05ec
        stw         r23,0x05e8,r0
        mfcr        r23
        stw         r23,0x05e4,r0
        xor         r0,r0,r0

#*****************************************************************
# set msr pow bit to go into sleep mode

        sync
        mfmsr r5                # get MSR
        addis r3, r0, 0x0004    # turn on POW bit
        ori   r3, r3, 0x0000    # turn on ME bit 19
        or    r5, r3, r5
        mtmsr r5
        isync

        addis r20, r0, 0x0000
        ori   r20, r20, 0x0002
stay_here:
        addic.  r20, r20, -1            # subtract 1 from r20 and set cc
        bgt cr0, stay_here              # loop if positive


# restore corrupted registers
        lwz         r23,0x05e4,r0
        mtcrf       0xff,r23
        lwz         r23,0x05e8,r0
        lwz         r22,0x05ec,r0
        mtspr       srr1, r22
        lwz         r21,0x05f0,r0
        mtspr       srr0, r21
        lwz         r20,0x05f4,r0
        lwz         r0,0x05fc,r0

        sync
        rfi

#*****************************************************************
# to get out of sleep mode, do a Soft Reset
#*****************************************************************


.orig 0x00000100                    # Reset handler in low memory

# force big endian mode
        stw         r0,0x05f8,r0       # need nop every second inst to make
#code read and execute in program order (up until the isync).
        stw         r0,0x05fc,r0
        mfmsr       r0
        ori         r0,r0,r0
        ori         r0,r0,0x0001            # force big endian LE bit
        ori         r0,r0,r0
        xori        r0,r0,0x0001            # force big endian LE bit
        ori         r0,r0,r0
```


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```
        mtmsr       r0
        ori         r0,r0,r0
        isync
        ori         r0,r0,r0

# save off additional registers to be corrupted
        stw         r20,0x05f4,r0
        stw         r21,0x05f0,r0
        stw         r22,0x05ec,r0
        stw         r23,0x05e8,r0
        mfcr        r23
        stw         r23,0x05e4,r0
        xor         r0,r0,r0

# restore corrupted registers
        lwz         r23,0x05e4,r0
        mtcrf       0xff,r23
        lwz         r23,0x05e8,r0
        lwz         r22,0x05ec,r0
        lwz         r21,0x05f0,r0
        lwz         r20,0x05f4,r0
        lwz         r0,0x05fc,r0

        sync
        rfi
#*********************************************************************
```

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Chapter 15
Debug Features

The MPC8240 provides several features to aid in starting-up and debugging the system. This chapter describes the following functions:

- Address attributes signals—Identification of the source and type of transaction currently being performed on either the PCI or memory interface.
- Debug address signals—Supplementation of the DRAM column address and chip select signals, allowing the system to reconstruct the corresponding physical address on the internal peripheral logic bus in a single cycle.
- $\overline{\text{MIV}}$ signal—Marking of valid address and data bus cycles on the memory bus.
- Memory data path error injection/capture—Injection of multi-bit stuck-at faults onto the peripheral logic or memory data/parity buses and capture the data/parity upon the receipt of an ECC or parity error
- JTAG/testing support

15.1 Debug Register Summary

The only debug registers in the MPC8240 are the six memory data path diagnostic registers consisting of three error injection mask registers and three error capture monitor registers. mapped as follows:

- Embedded utilities memory block (EUMBBAR) for local bus accesses at offsets 0xF_F000 to 0xF_FFFF
- Embedded utilities peripheral control and status registers (PCSRBAR) for PCI bus accesses at offsets 0xF00 to 0xFFF

Note that this data path diagnostic register space is also shared with the watchpoint registers described in Chapter 16, “Programmable I/O and Watchpoint.” The offsets to individual registers are defined in Table 15-1.The memory data path error injection/capture functionality is described in more detail in Section 15.5, “Memory Data Path Error Injection/Capture.” Note that while these registers are mapped from local bus offset 0xF_F000 to 0xF_F014 (PCI offset 0xF00 to 0xF14), the watchpoint registers are mapped from the local bus offset 0xF_F018 though 0xF_F042 (PCI offset 0xF18 to 0xF42).

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Table 15-1. Memory Data Path Diagnostic Register Offsets

Local Bus Offset	PCI Bus Offset	Size (bytes)	Program Access Size (bytes)	Register	Register Access	Reset Value
0xF_F000	0xF00	4	4	MDP_ERR_INJ_MASK_DH	R/W	0x0000_0000
0xF_F004	0xF04	4	4	MDP_ERR_INJ_MASK_DL	R/W	0x0000_0000
0xF_F008	0xF08	4	1, 2, or 4	MDP_ERR_INJ_MASK_PAR	R/W	0x0000_0000
0xF_F00C	0xF0C	4	4	MDP_ERR_CAP_MON_DH	R	0x0000_0000
0xF_F010	0xF10	4	4	MDP_ERR_CAP_MON_DL	R	0x0000_0000
0xF_F014	0xF14	4	1, 2, or 4	MDP_ERR_CAP_MON_PAR	R/W	0x0000_0000

15.2 Address Attribute Signals

The MPC8240 provides additional information corresponding to memory and PCI activity on several signals in order to assist with system debug. These signals are the memory attribute signals (MAA[0:2]) and the PCI attribute signals (PMAA[0:2]) as summarized in Table 15-2.

Table 15-2. Address Attribute Signal Summary

Signal Name	Pins	I/O	Signal Meaning
MAA[0:2]	3	O	Memory address attributes
PMAA[0:2]	3	O	PCI address attributes

15.2.1 Memory Address Attribute Signals (MAA[0:2])

The memory attribute signals are associated with the memory interface and provide information about the source of the memory operation being performed by the MPC8240.

The encodings of the memory address attribute signals are defined in Table 15-3.

Table 15-3. Memory Address Attribute Signal Encodings

MAA0	MAA1	MAA2	Memory Operation	Definition
0	0	0	read	Processor data read
0	0	1	read	Processor touch load
0	1	0	read	Processor instruction fetch
0	1	1	—	Reserved
1	0	0	read	PCI memory read
1	0	1	read	DMA channel 0 memory read
1	1	0	read	DMA channel 1 memory read
1	1	1	—	Reserved
0	0	0	write	Processor data write

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Table 15-3. Memory Address Attribute Signal Encodings (Continued)

0	0	1	—	Reserved
0	1	0	—	Reserved
0	1	1	—	Reserved
1	0	0	write	PCI memory write
1	0	1	write	DMA channel 0 memory write
1	1	0	write	DMA channel 1 memory write
1	1	1	—	Reserved

15.2.2 Memory Address Attribute Signal Timing

The memory address attribute signals have timing characteristics as shown in Figure 15-8 through Figure 15-16. These figures also show the relationship of MAA[0:2] with the $\overline{\text{MIV}}$ signal. Note that the attribute signals are valid at the same time as the column address for all DRAM accesses including single-beat, burst, 32- and 64-bit modes, page misses, page hits and others. Note that for all ROM/Flash accesses the attribute signals are valid when the address is valid.

15.2.3 PCI Address Attribute Signals

The PCI address attribute signals provide information about the source of the PCI operation being performed by the MPC8240, and the encodings are defined in Table 15-4.

Table 15-4. PCI Attribute Signal Encodings

PMAA0	PMAA1	PMAA2	PCI Operation	Definition
0	0	0	read	Processor data load
0	0	1	read	Processor touch load
0	1	0	read	Processor instruction fetch
0	1	1	—	reserved
1	0	0	—	reserved
1	0	1	read	DMA channel 0 PCI read
1	1	0	read	DMA channel 1 PCI read
1	1	1	read	PCI address bus invalid
0	0	0	write	Processor data write
0	0	1	—	reserved
0	1	0	—	reserved
0	1	1	—	reserved
1	0	0	—	reserved
1	0	1	write	DMA channel 0 PCI write

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Table 15-4. PCI Attribute Signal Encodings (Continued)

1	1	0	write	DMA channel 1 PCI write
1	1	1	write	PCI address bus invalid

15.2.4 PCI Address Attribute Signal Timing

The PCI attribute signals have timing characteristics as shown in Figure 15-1 and Figure 15-2. Note that the attribute signals are valid at the same time as the address for all MPC8240-sourced PCI accesses. During all other clock cycles, PMAA[0:2] are held at the value 0b111.

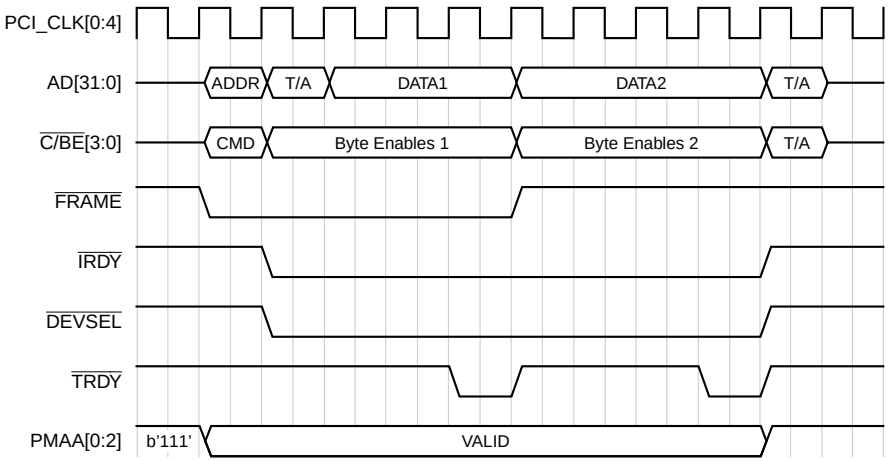

Figure 15-1. Example PCI Address Attribute Signal Timing for Burst Read Operations

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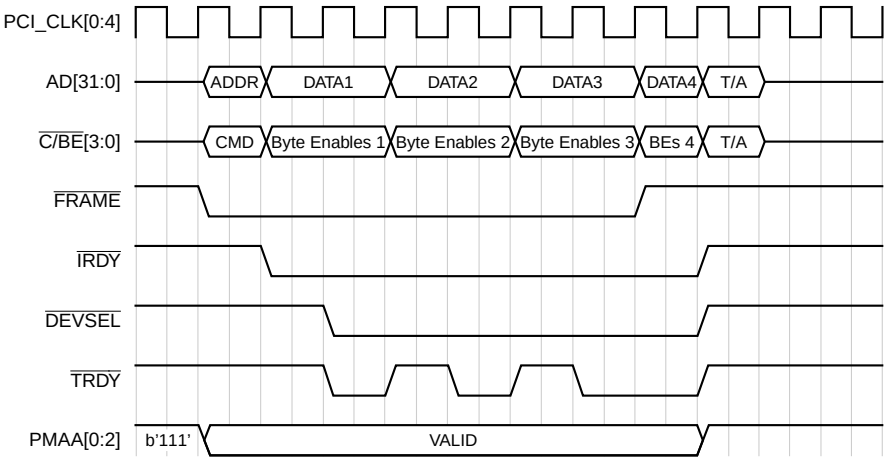

Figure 15-2. Example PCI Address Attribute Signal Timing for Burst Write Operations

15.3 Memory Debug Address

When enabled, the debug address gives software disassemblers a simple way to reconstruct the 30-bit physical address for a memory bus transaction to DRAM, SDRAM, ROM, Flash, or Port X. For DRAM or SDRAM, these 16 debug address signals are sampled with the column address and chip-selects. For ROM, Flash, and Port X devices, the debug address pins are sampled at the same time as the ROM address and can be used to recreate the 24-bit physical address in conjunction with ROM address. The granularity of the reconstructed physical address is limited by the bus width of the interface; double words for 64-bit interfaces, words for 32-bit interfaces, and bytes for 8-bit interfaces.

15.3.1 Enabling Debug Address

The debug address functionality is enabled or disabled at reset by using the $\overline{\text{GNT4}}$ reset configuration signal. If the $\overline{\text{GNT4}}$ signal is left floating at reset, an internal pull-up forces it high, disabling the debug address functionality. If $\overline{\text{GNT4}}$ is asserted at reset (driven low), the debug address functionality is enabled. See Section 2.4, “Configuration Signals Sampled at Reset,” for a complete description of all the reset configuration signals.

Additionally the debug address functionality can be enabled by the setting of the DEBUG_ADDR_ bit in the WP_CONTROL register. See Section 16.2.4, “Watchpoint Control Register (WP_CONTROL),” for more information.

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15.3.2 Debug Address Signal Definitions

Table 15-5 describes the mapping of all the memory debug address signals and their alternate functions. Note that while DA[15:0] are all outputs when used as the debug address signals, the alternate functions for some of these signals are defined as inputs.

Table 15-5. Memory Debug Address Signal Definitions

Signal	Signal Meaning	Alternate Function	Pins	I/O
DA[15:11]	debug_address[15–11]	—	5	O
DA[10:6]	debug_address[10–6]	PLL_CFG[0:4]	5	O
DA5	debug_address 5	$\overline{\text{GNT4}}$	1	O
DA4	debug_address 4	$\overline{\text{REQ4}}$	1	O
DA3	debug_address 3	PCI_CLK4	1	O
DA2	debug_address 2	—	1	O
DA1	debug_address 1	CKO	1	O
DA0	debug_address 0	$\overline{\text{QACK}}$	1	O
$\overline{\text{GNT4}}$	Debug address enable (during reset configuration). 0 Debug address enabled; partial address of the transaction driven on DA[15:0]. 1 Debug address disabled	$\overline{\text{GNT4}}$; DA5	1	I

15.3.3 Physical Address Mappings

The physical address mappings for 64- and 32-bit DRAM and SDRAM are depicted in Figure 15-3 and Figure 15-4. The physical address mappings for 64-, 32-, and 8-bit ROM/Flash are depicted in Figure 15-5, Figure 15-6, and Figure 15-7 respectively. The encoded version of $\overline{\text{RAS}}$[0:7] shown in the figures is described in Section 15.3.4, “RAS Encoding.”

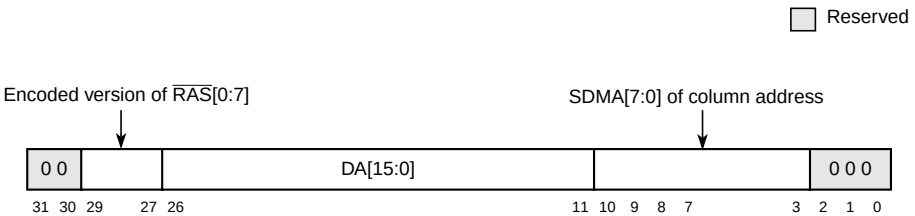

Figure 15-3. 64-Bit Mode, DRAM and SDRAM Physical Address for Debug

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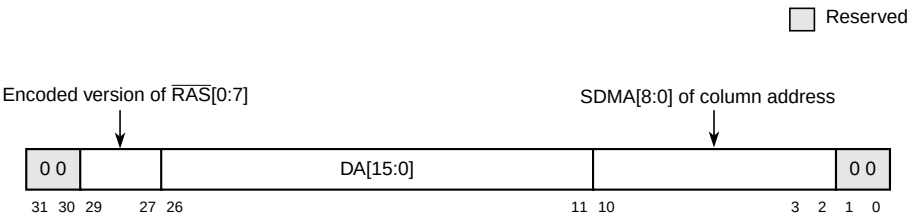

Figure 15-4. 32-Bit Mode, DRAM and SDRAM Physical Address for Debug

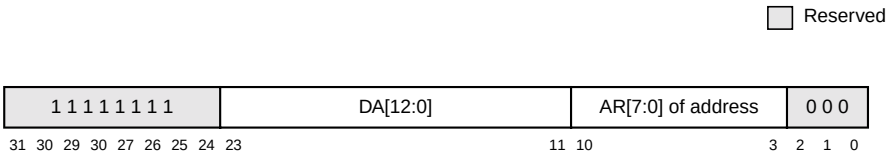

Figure 15-5. 64-Bit Mode, ROM and Flash Physical Address for Debug

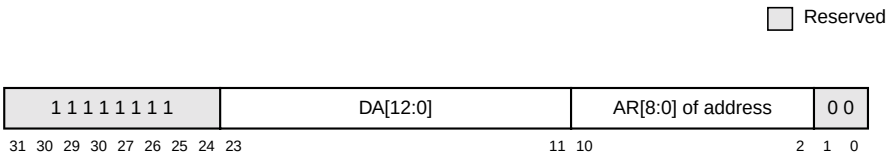

Figure 15-6. 32-Bit Mode, ROM and Flash Physical Address for Debug

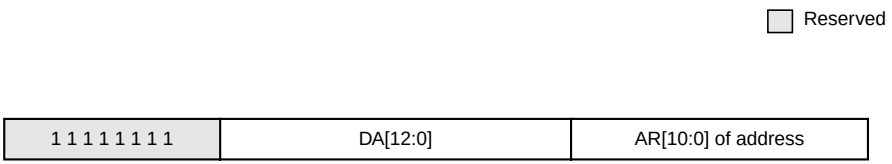

Figure 15-7. 8-Bit Mode, ROM and Flash Physical Address for Debug

15.3.4 $\overline{\text{RAS}}$ Encoding

The encoding of $\overline{\text{RAS}}/\overline{\text{CS}}$[0:7] to form bits 29–27 of the physical address for DRAM and SDRAM transactions is based on the memory bank configuration as programmed in the bank starting and ending address configuration registers located at offsets 0x80, 0x84, 0x88, 0x8C, 0x90, 0x94, 0x98, and 0x9C. For this encoding algorithm to be deterministic, DRAM and SDRAM banks are not allowed to cross a 128-Mbyte address partition (that is, the starting and ending address for any one bank must fall within the same 128-Mbyte partition). Obviously, such $\overline{\text{RAS}}$ information is relevant only for DRAM (and SDRAM) and not for ROM/Flash. For a simple example of $\overline{\text{RAS}}$ encodings, see Table 15-6 below.

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Table 15-6. Example of $\overline{\text{RAS}}$ Encoding For 568-Mbyte Memory System

Partition	Encoded $\overline{\text{RAS}}$: Physical Address [29–27]	Address		Bank	Bank Size	$\overline{\text{RAS}}$[0:7]
Eighth 128-Mbyte partition of 1 Gbyte main memory	0b111	Ending	0x3FF	undefined		
		Starting	0x380			
Seventh 128-Mbyte partition of 1 Gbyte main memory	0b110	Ending	0x37F	undefined		
		Starting	0x300			
Sixth 128-Mbyte partition of 1 Gbyte main memory	0b101	Ending	0x2FF	undefined		
		Starting	0x280			
Fifth 128-Mbyte partition of 1Gbyte main memory	0b100	Ending	0x27F	undefined		
		Starting	0x238			
		Ending	0x237	7	8 MBytes	0xFE
		Starting	0x230			
		Ending	0x22F	6	16 MBytes	0xFD
		Starting	0x220			
		Ending	0x21F	5	32 MBytes	0xFB
		Starting	0x200			
Fourth 128-Mbyte partition of 1 Gbyte main memory	0b011	Ending	0x1FF	4	64 MBytes	0xF7
		Starting	0x1C0			
		Ending	0x1BF	3	64 MBytes	0xEF
		Starting	0x180			
Third 128-Mbyte partition of 1 Gbyte main memory	0b010	Ending	0x17F	1	128 MBytes	0xBF
		Starting	0x100			
Second 128-Mbyte partition of 1 Gbyte main memory	0b001	Ending	0x0FF	2	128 MBytes	0xDF
		Starting	0x080			
First 128-Mbyte partition of 1 Gbyte main memory	0b000	Ending	0x07F	0	128 MBytes	0x7F
		Starting	0x000			

15.3.5 Debug Address Timing

For examples of debug address timing for various memory types, see Figure 15-8 through Figure 15-16.

15.4 Memory Interface Valid ($\overline{\text{MIV}}$)

The memory interface valid signal $\overline{\text{MIV}}$ is asserted whenever FPM, EDO, SDRAM, Flash, or ROM addresses or data are present on the external memory bus. It is intended to help reduce the number of bus cycles that logic analyzers must store in memory during a debug trace and is described in Table 15-7. The $\overline{\text{MIV}}$ signal should be sampled with the rising edge of SDRAM_CLK[0:3].

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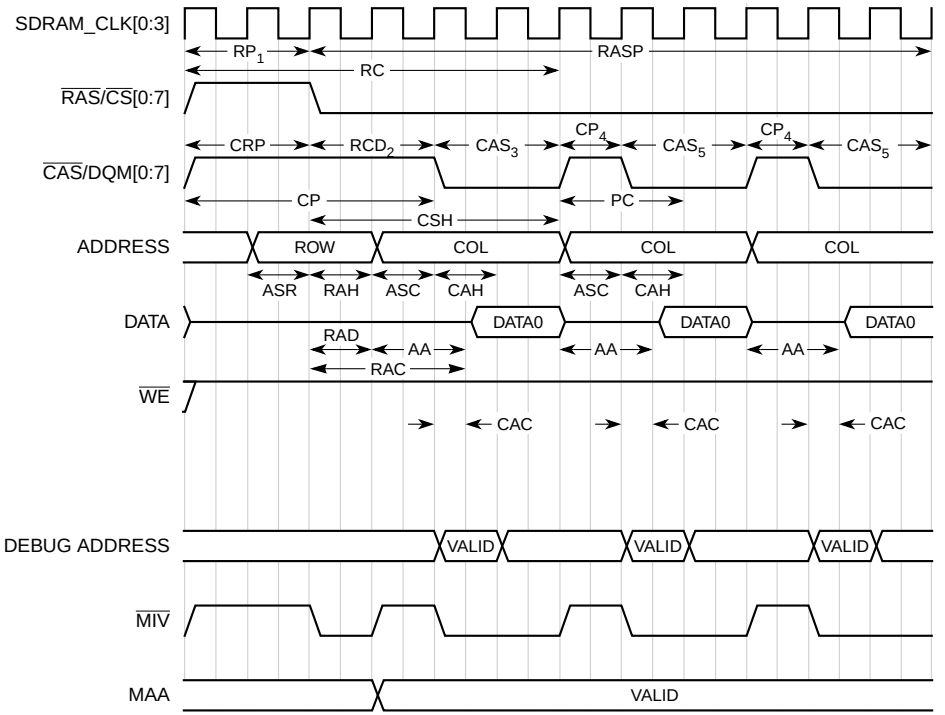
Table 15-7. Memory Interface Valid Signal Definition

Signal Name	Pins	Active	I/O	Signal Meaning
$\overline{MIV}$	1	Low	O	Indicates that the transaction address or data is valid on the memory bus.

15.4.1 $\overline{MIV}$ Signal Timing

The $\overline{MIV}$ signal is an active low signal and has timing characteristics as shown in Figure 15-8 through Figure 15-16.



NOTES:

1. Subscripts identify programmable timing variables (RP_1, RCD_2, CAS_3).
2. $\overline{MIV}$ asserts for address and control on the first clock cycle that $\overline{RAS}$ or $\overline{CAS}$ is asserted for a read.
3. $\overline{MIV}$ asserts for data on the last clock cycle that $\overline{CAS}$ is asserted for a read.

Figure 15-8. Example FPM Debug Address, $\overline{MIV}$, and MAA Timings for Burst Read Operation

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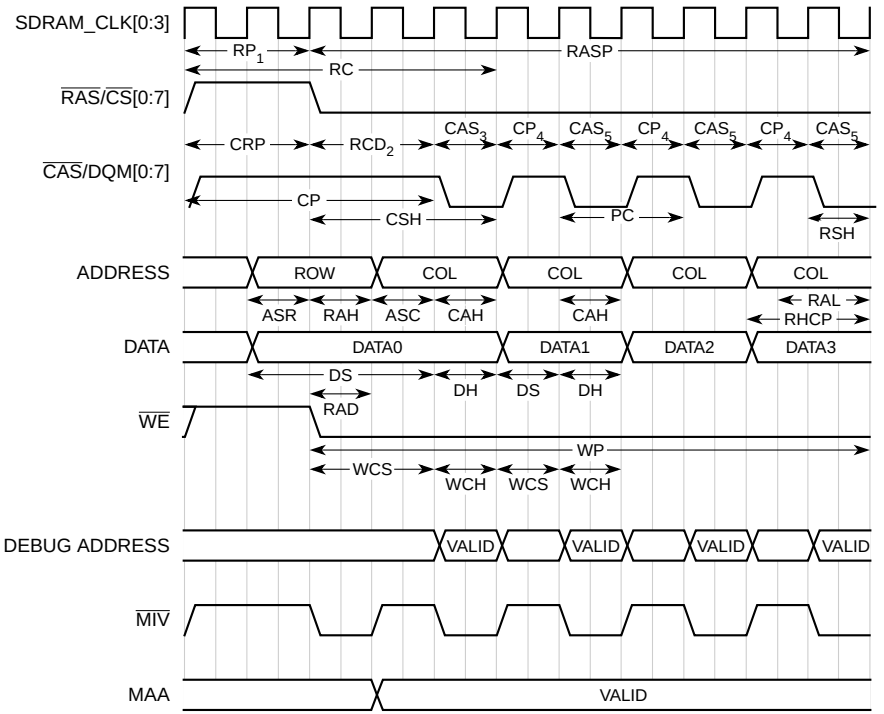

NOTES:

1. Subscripts identify programmable timing variables (RP_1, RCD_2, CAS_3).
2. $\overline{MIV}$ asserts for address, control, and data on the first clock cycle that $\overline{RAS}$ or $\overline{CAS}$ is asserted for a write.

Figure 15-9. Example FPM Debug Address, $\overline{MIV}$, and MAA Timings for Burst Write Operation

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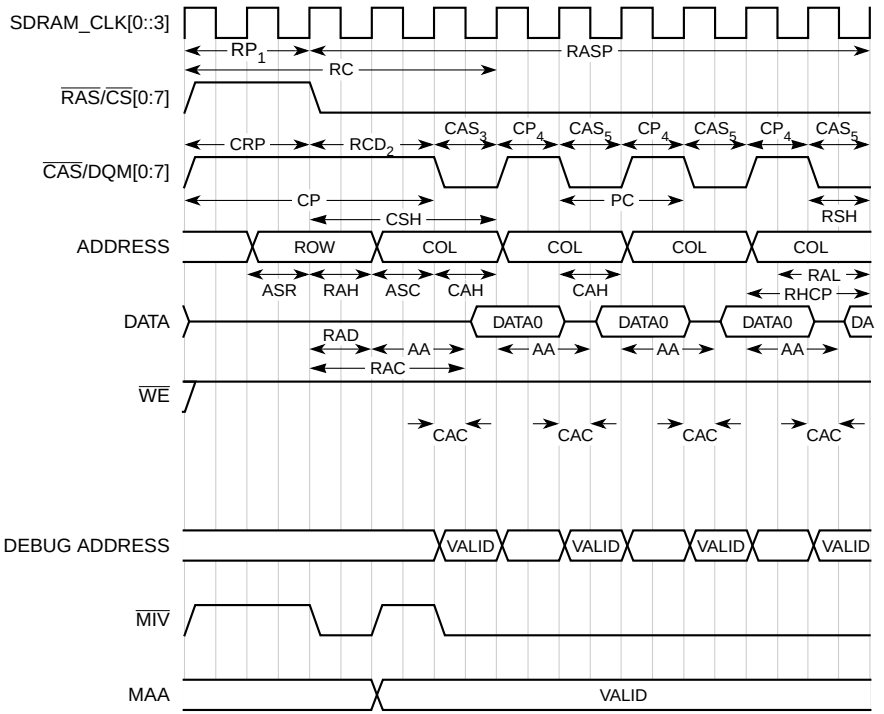

NOTES:

1. Subscripts identify programmable timing variables (RP_1, RCD_2, CAS_3).
2. $\overline{MIV}$ asserts for address and control on the first clock cycle that $\overline{RAS}$ or $\overline{CAS}$ is asserted for a read.
3. $\overline{MIV}$ asserts for data on the same clock cycle that $\overline{CAS}$ negates for a read.

Figure 15-10. Example EDO Debug Address, $\overline{MIV}$, and MAA Timings for Burst Read Operation

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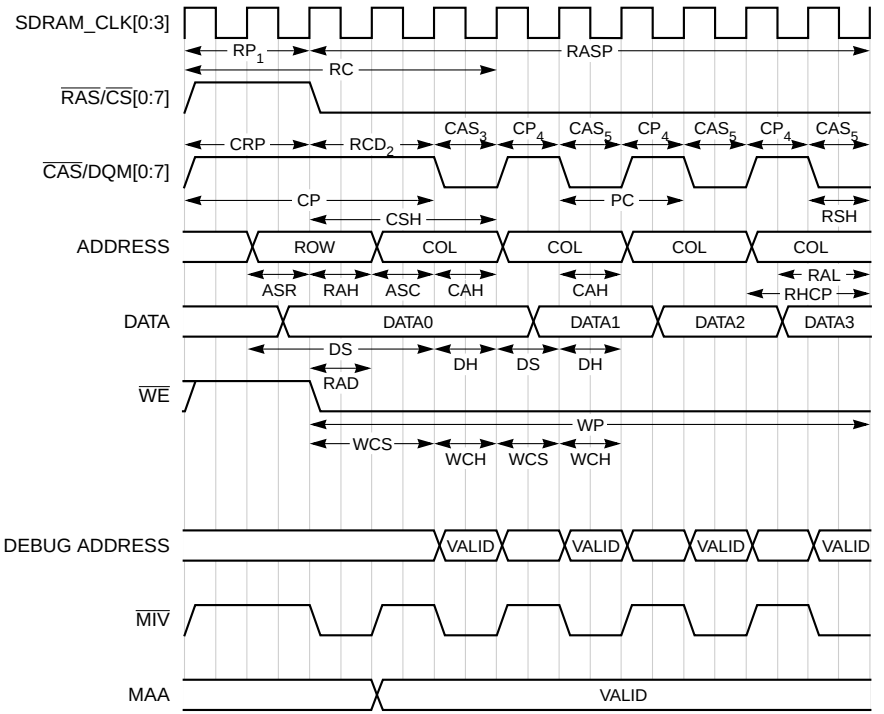

NOTES:

1. Subscripts identify programmable timing variables (RP_1, RCD_2, CAS_3).
2. $\overline{MIV}$ asserts for address, control, and data on the first clock cycle that $\overline{RAS}$ or $\overline{CAS}$ is asserted for a write.

Figure 15-11. Example EDO Debug Address, $\overline{MIV}$, and MAA Timings for Burst Write Operation

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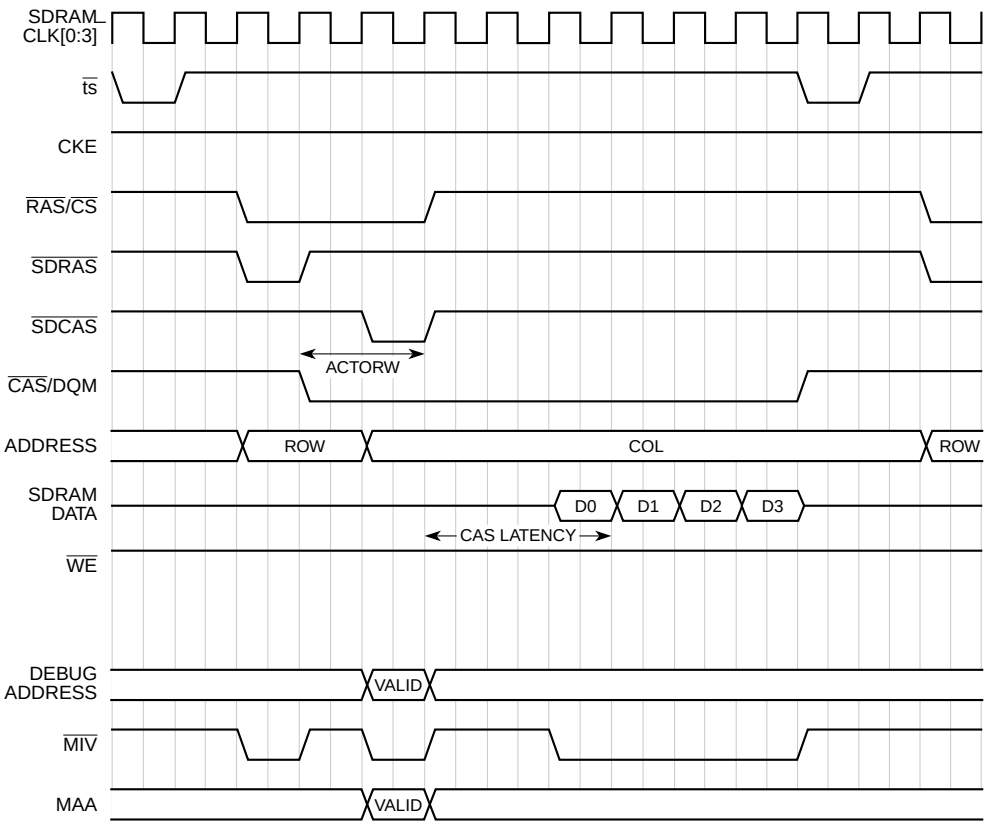

Figure 15-12. Example SDRAM Debug Address, MIV, and MAA Timings for Burst Read Operation

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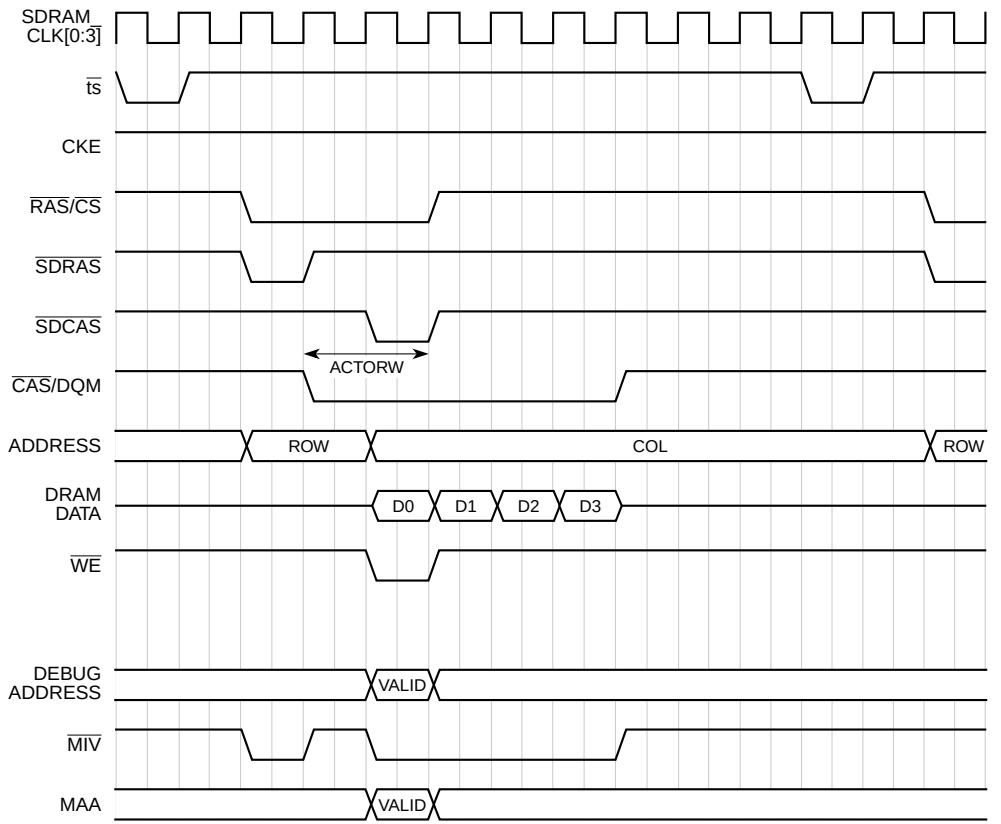

Figure 15-13. Example SDRAM Debug Address, MIV, and MAA Timings for Burst Write Operation

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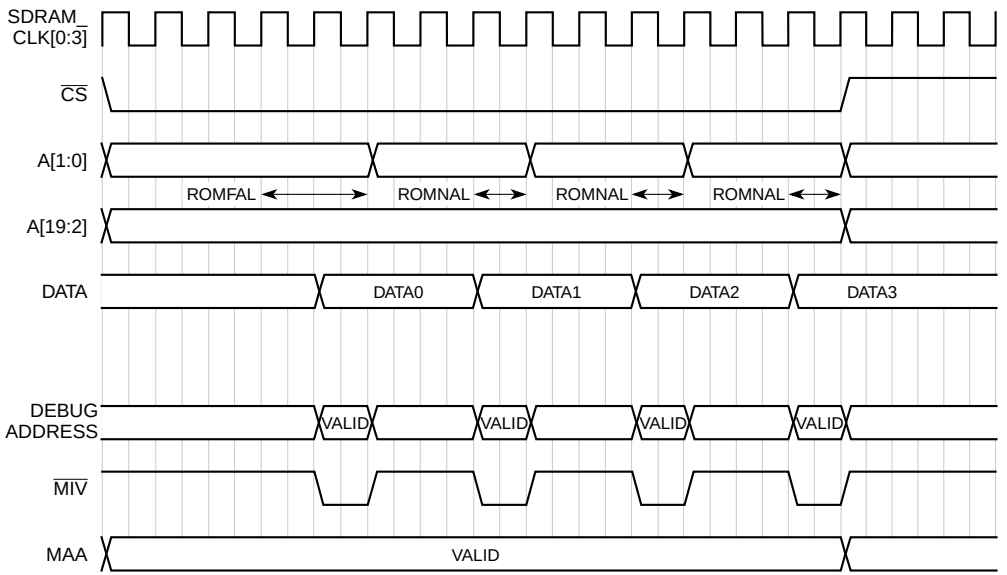

NOTES:

1. ROMFAL (ROM First Access Latency) = 0–15 clocks.
2. ROMNAL (ROM Nibble Access Latency) = 0–9 clocks.
3. Memory configuration BURST = 1.

Figure 15-14. Example ROM Debug Address, $\overline{\text{MIV}}$, and MAA Timings For Burst Read

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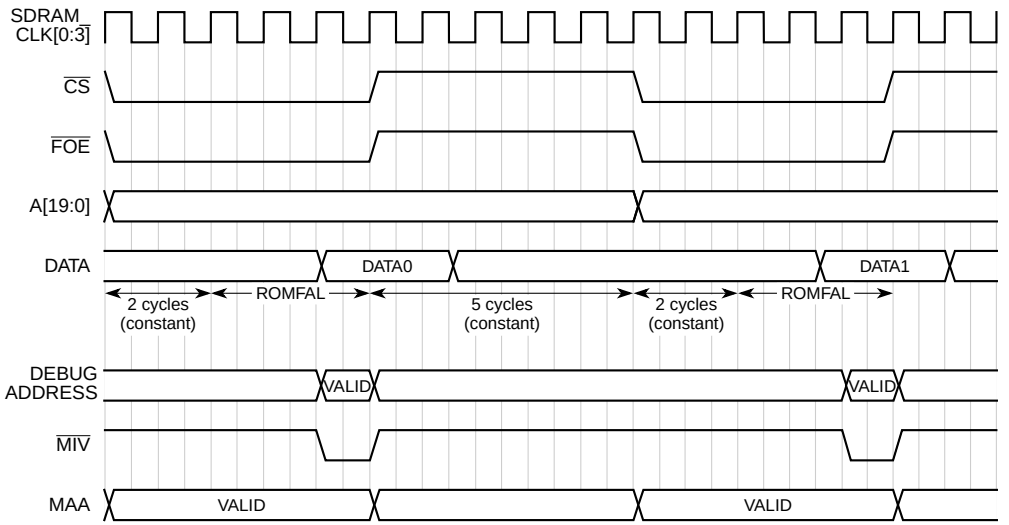
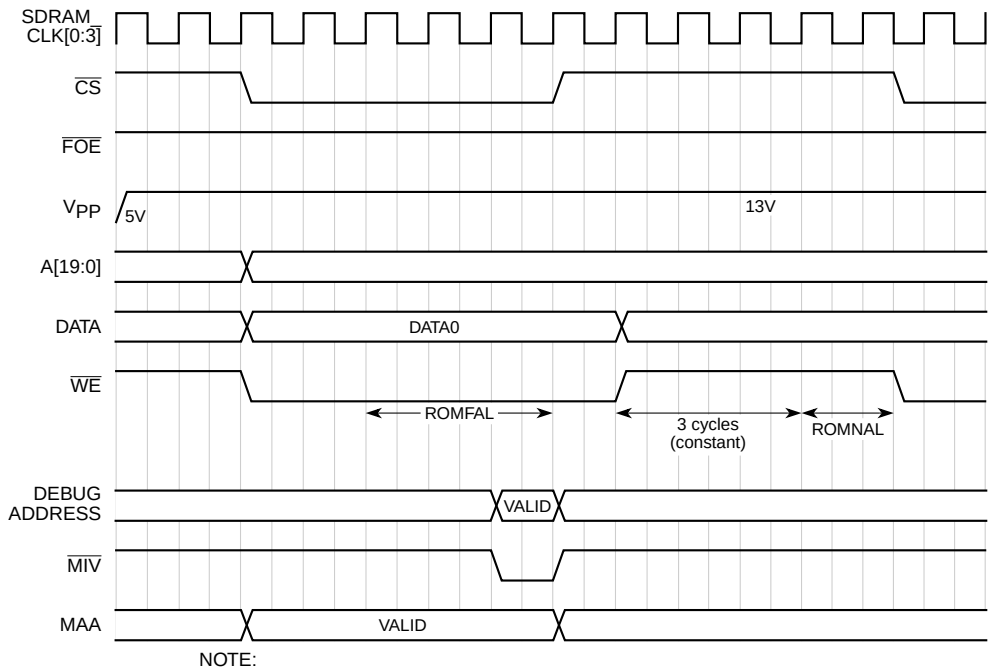


Figure 15-15. Example Flash Debug Address, MIV, and MAA Timings For Single-Byte Read



NOTE:
1. V_{PP} multiplexed by system logic with appropriate setup time to write cycle.

Figure 15-16. Example Flash Debug Address, MIV, and MAA Timings for Write Operation

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15.5 Memory Data Path Error Injection/Capture

The MPC8240 provides hardware to exercise and debug the on-chip ECC and parity logic by allowing the user to inject multi-bit stuck-at faults onto the peripheral logic or memory data/parity buses and to capture the data/parity upon the receipt of an ECC or parity error.

The memory data path error injection/capture system is programmed via the six memory data path diagnostic registers. These registers allow the user to program error injection masks and to monitor ECC/parity error capture data. The memory data path diagnostic registers are accessible from either the local bus or PCI port. All memory data path diagnostic registers are reset to zero, 0x0000_0000, unless otherwise specified.

15.5.1 Memory Data Path Error Injection Mask Registers

The memory data path error injection masks are used to inject errors onto the internal peripheral logic bus or the memory data/parity buses as shown in Figure 15-23. Separate mask registers are provided for the high data, low data, and parity buses. The masks are bit-wise inverting; a 0b1 in the mask causes the corresponding bit on the data/parity bus to be inverted. The masks are applied to the read and/or write data path by read and write mask enable bits. These registers can be read or written and are initialized to 0x0000_0000.

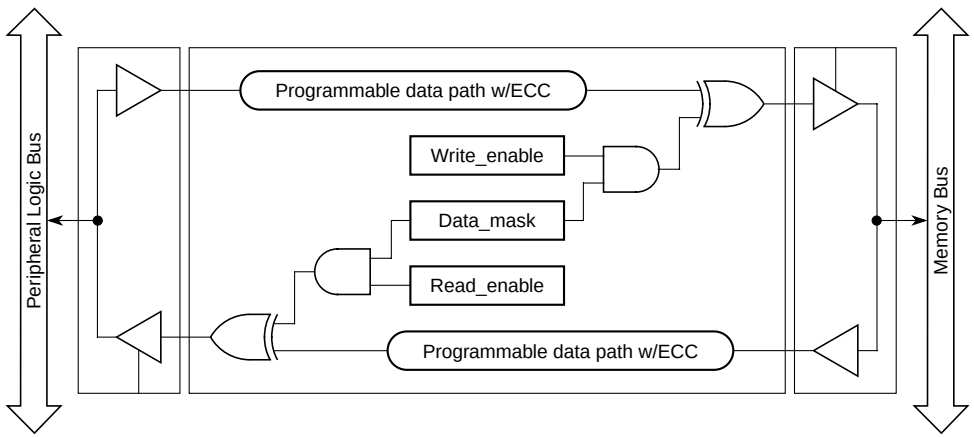

Figure 15-17. Functional Diagram of Memory Data Path Error Injection

15.5.1.1 DH Error Injection Mask Register

Figure 15-18 shows the bits of the DH error injection mask register.

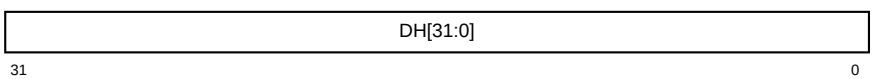

Figure 15-18. DH Error Injection Mask (MDP_ERR_INJ_MASK_DH)—Offsets 0xF_F000, 0xF00

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Figure 15-8 shows the bit definitions of the DH error injection mask register.

Table 15-8. DH Error Injection Mask Bit Field Definitions

Bits	Name	Reset Value	R/W	Description
31–0	DH[31:0]	all 0s	R/W	Error injection mask for memory data path data bus high

15.5.1.2 DL Error Injection Mask Register

Figure 15-19 shows the bits of the DL error injection mask register.

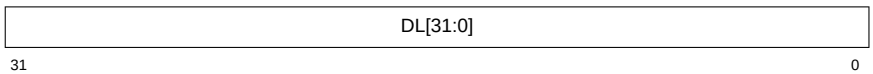

Figure 15-19. DL Error Injection Mask (MDP_ERR_INJ_MASK_DL)—Offsets 0xF_F004, 0xF04

Figure 15-9 shows the bit definitions of the DL error injection mask register

Table 15-9. DL Error Injection Mask Bit Field Definitions

Bits	Name	Reset Value	R/W	Description
31–0	DL[31:0]	all 0s	R/W	Error injection mask for memory data path data bus low

15.5.1.3 Parity Error Injection Mask Register

Figure 15-20 shows the bits of the DH error injection mask register and Table 15-10 shows the bit definitions.

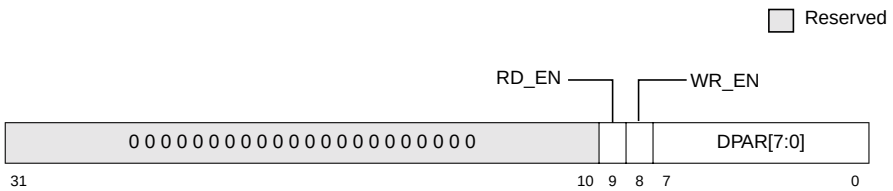

Figure 15-20. Parity Error Injection Mask (MDP_ERR_INJ_MASK_PAR)—Offsets 0xF_F008, 0xF08

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Table 15-10. Parity Error Injection Mask Bit Field Definitions

Bits	Name	Reset Value	R/W	Description
31–8	—	all 0s	Read	Reserved
9	RD_EN	0	R/W	Memory data path read enable bit 0 Disables error injection for reads 1 Enables error injection onto the peripheral logic data bus during reads from local memory
8	WR_EN	0	R/W	Memory data path write enable bit 0 Disables error injection for writes 1 Enables error injection onto the memory data bus during writes to local memory
7–0	DPAR[7:0]	0b0000_0000	R/W	Error injection mask for memory data parity bus

15.5.2 Memory Data Path Error Capture Monitor Registers

The memory data-path error capture monitors are used to latch data that causes ECC or parity errors from either the internal peripheral logic bus or the memory data/parity bus. Separate monitors are provided for the high data, low data, and parity buses. The monitors are read-only. They are loaded automatically when the error detection registers detect any of the following:

- A memory read parity error / single-bit ECC error trigger exceeded; EDR1[2]
- A multi-bit ECC error; EDR2[3]
- A write parity error; EDR2[2]

When memory data path parity/ECC error data is loaded into the monitors, the capture flag in the MDP_ERR_CAP_MON_PAR is also set. This control bit remains set until explicitly cleared by the software. The set capture flag prevents subsequent errors from overwriting the data from the first failure. The capture flag is the only bit in the memory data path error capture monitors that is read/write.

15.5.2.1 DH Error Capture Monitor Register

Figure 15-21 shows the bits of the DH error capture monitor register.

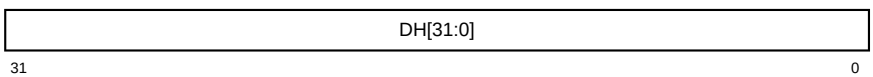

Figure 15-21. DH Error Capture Monitor (MDP_ERR_CAP_MON_DH)—Offsets 0xF_F00C, 0xF0C

Table 15-11 shows the bit definitions of the DH error capture monitor register.

Table 15-11. DH Error Capture Monitor Bit Field Definitions

Bits	Name	Reset Value	R/W	Description
31–0	DH[31:0]	all 0s	Read	Capture monitor for memory data path data bus high

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15.5.2.2 DL Error Capture Monitor Register

Figure 15-21 shows the bits of the DL error capture monitor register.

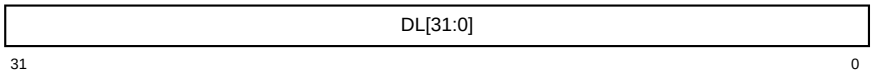

Figure 15-22. DL Error Capture Monitor (MDP_ERR_CAP_MON_DL)—Offsets 0xF_F010, 0xF10

Table 15-12 shows the bit definitions of the DL error capture monitor register.

Table 15-12. DL Error Capture Monitor Bit Field Definitions

Bits	Name	Reset Value	R/W	Description
31–0	DL[31:0]	all 0s	Read	Capture monitor for memory data path data bus low

15.5.2.3 Parity Error Capture Monitor Register

Figure 15-23 shows the bits of the parity error capture monitor register and Table 15-13 shows the bit definitions.

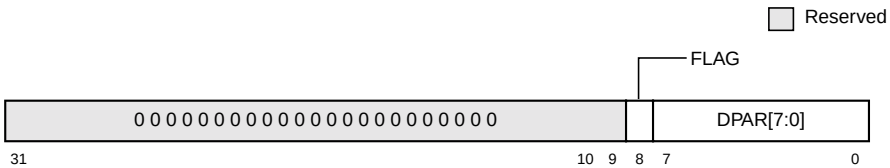

Figure 15-23. Parity Error Capture Monitor (MDP_ERR_CAP_MON_PAR)—Offsets 0xF_F014, 0xF14

Table 15-13. Parity Error Capture Monitor Bit Field Definitions

Bits	Name	Reset Value	R/W	Description
31–9	—	all 0s	Read	Reserved
8	FLAG	0	R/W	Capture flag 0 No data captured 1 Data valid
7–0	DPAR[7:0]	0b0000_0000	Read	Capture monitor for memory data path data parity bus

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15.6 JTAG/Testing Support

The MPC8240 provides a joint test action group (JTAG) interface to facilitate boundary-scan testing. The JTAG interface complies to the IEEE 1149.1 boundary-scan specification. For additional information about JTAG operations, refer to the IEEE 1149.1 specification.

The JTAG interface consists of a set of five signals, three JTAG registers, and a test access port (TAP) controller, described in the following sections. A block diagram of the JTAG interface is shown in Figure 15-24.

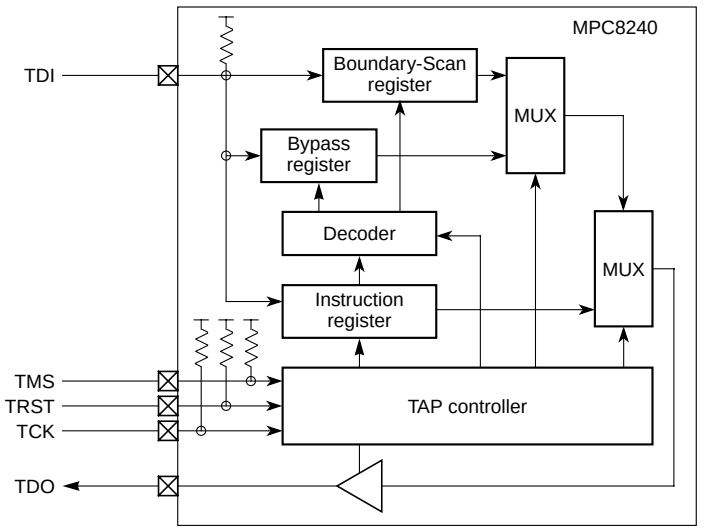

Figure 15-24. JTAG Interface Block Diagram

15.6.1 JTAG Signals

The MPC8240 provides five dedicated JTAG signals—test data input (TDI), test mode select (TMS), test reset ($\overline{\text{TRST}}$), test clock (TCK), and test data output (TDO). The TDI and TDO signals are used to input and output instructions and data to the JTAG scan registers. The boundary-scan operations are controlled by the TAP controller through commands received by means of the TMS signal. Boundary-scan data is latched by the TAP controller on the rising edge of the TCK signal. The $\overline{\text{TRST}}$ signal is specified as optional by the IEEE 1149.1 specification and is used to reset the TAP controller asynchronously. The assertion of the $\overline{\text{TRST}}$ signal at power-on reset ensures that the JTAG logic does not interfere with the normal operation of the MPC8240.

Section 2.2.6, “Test and Configuration Signals,” provides more detailed information on the JTAG signals.

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15.6.2 JTAG Registers and Scan Chains

The bypass, boundary-scan, and instruction JTAG registers and their associated scan chains are implemented by the MPC8240. These registers are mandatory for compliance with the IEEE 1149.1 specification.

15.6.2.1 Bypass Register

The bypass register is a single-stage register used to bypass the boundary-scan latches of the MPC8240 during board-level boundary-scan operations involving components other than the MPC8240. The use of the bypass register reduces the total scan string size of the boundary-scan test.

15.6.2.2 Boundary-Scan Registers

The JTAG interface provides a chain of registers dedicated to boundary-scan operations. To be JTAG-compliant, these registers cannot be shared with any functional registers of the MPC8240. The boundary-scan register chain includes registers controlling the direction of the input/output drivers in addition to the registers reflecting the signal value received or driven.

The boundary-scan registers capture the input or output state of the MPC8240's signals during a Capture_DR TAP controller state. When a data scan is initiated following the Capture_DR state, the sampled values are shifted out through the TDO while new boundary-scan register values are shifted in through the TDI. At the end of the data scan operation, the boundary-scan registers are updated with the new values during an Update_DR TAP controller state.

15.6.2.3 Instruction Register

The 8-bit JTAG instruction register serves as an instruction and status register. As TAP controller instructions are scanned in through the TDI input, the TAP controller status bits are scanned out through the TDO output.

15.6.2.4 TAP Controller

The MPC8240 provides a standard JTAG TAP controller that controls instruction and data scan operations. The TMS signal controls the state transitions of the TAP controller.

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Chapter 16
Programmable I/O and Watchpoint

The MPC8240 programmable I/O and watchpoint facility allows system designers to monitor the state of the internal peripheral logic (interface between the processor core and the peripheral logic block) bus and trigger an output signal as shown in Figure 16-1. The user programs up to two sets of fully maskable 58-bit triggers called watchpoints on the peripheral logic address and control buses. Once enabled, the watchpoint facility scans the peripheral logic bus for a user-programmable sequence of matches to these watchpoints.Note that the peripheral logic bus signals are analogous to the 60x bus signals on the MPC603e and throughout this chapter, they are referenced as the corresponding external signals in the *MPC603e User's Manual*.

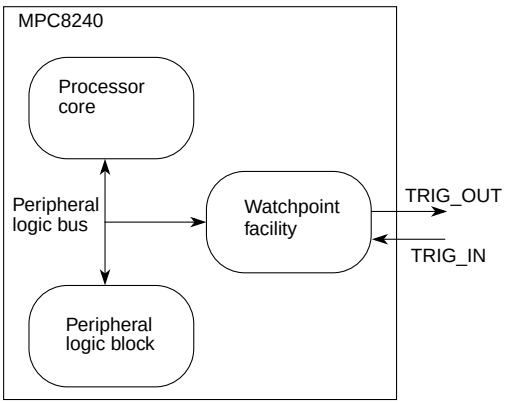

Figure 16-1. Watchpoint Facility Signal Interface

Each watchpoint has a dedicated, user programmable, 4-bit match count register. The value programmed into the count register determines the number of times the associated watchpoint must match the state of the peripheral logic bus before the watchpoint facility generates a final match. Upon a final match, the watchpoint facility can be programmed to generate an external trigger pulse on the TRIG_OUT signal. The watchpoint facility can be programmed to disable itself and stop scanning (one-shot scan mode) following a trigger pulse, or to continue to scan for the next occurrence of the trigger match (continuous scan mode) until explicitly disabled by the user. The following features are provided by the watchpoint facility:

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- Two watchpoints with 58-bit triggers (signal-by-signal comparison on peripheral logic address and control bus) that control a single TRIG_OUT signal.
- TRIG_IN signal for explicitly enabling and disabling the watchpoint facility and for exiting hold state
- A bit-wise programmable ANDing mask of a watchpoint trigger for each watchpoint
- The ability to trigger only on the nth watchpoint match where n is user-programmable for each watchpoint
- One-shot scan mode for generating only one trigger match and then automatically disabling the watchpoint facility
- Continuous scan mode for generating multiple trigger matches
- Single, waterfall, OR, and AND NOT modes that determine the interaction between watchpoints #1 and #2 (including their counter registers)

16.1 Watchpoint Interface Signal Description

The watchpoint facility uses the TRIG_IN and TRIG_OUT signals. TRIG_IN serves multiple functions as described in the WP_CONTROL[WP_RUN] bit description of Section 16.2.4, “Watchpoint Control Register (WP_CONTROL).” TRIG_OUT has many programmable attributes as described in Table 16-7 of Section 16.2.4, “Watchpoint Control Register (WP_CONTROL).”

Table 16-1. Watchpoint Signal Summary

Signal Name	Pins	Active	I/0	Signal Meaning	Timing Comments	Related WP_CONTROL Bits
TRIG_OUT	1	Active high or active low depending on setting of WP_TRIG bit of WP_CONTROL	O	Indicates that the final watchpoint match has occurred as defined in WP_MODE field of WP_CONTROL.	If WP_TRIG_HOLD = 0, single cycle pulse. If WP_TRIG_HOLD = 1, asserted until user toggles TRIG_IN.	WP_TRIG_HOLD WP_MODE WP_TRIG
TRIG_IN	1	HIGH	I	Rising edge: If the watchpoint facility is in the HOLD state (WP_TRIG_HOLD=1 and TRIG_OUT is active), a rising edge on this signal causes the device to exit the HOLD state, release TRIG_OUT, and resume normal operation. Otherwise, pulsing this signal toggles the value of the WP_RUN bit. This allows the user to turn the watchpoint facility on and off externally.	Single cycle pulse	WP_TRIG_HOLD WP_RUN

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16.2 Watchpoint Registers

The watchpoint facility is programmed through the watchpoint registers. These registers allow the user to program watchpoint triggers and masks. Two sets of watchpoint triggers and masks are supported, one for watchpoint #1 and another for watchpoint #2. In addition, the watchpoint control register is used to configure the debug address function of the MPC8240

The watchpoint registers are accessible from either the local bus or the PCI bus. The WP_CONTROL[WP_RUN] bit is the only bit that can be changed while the watchpoint facility is enabled (while WP_RUN = 1). Changing any other values in the watchpoint registers while WP_RUN = 1 is not supported and results in unpredictable behavior.

16.2.1 Watchpoint Register Address Map

The watchpoint registers reside in an area of the embedded utilities block that is shared by the memory data path diagnostic registers and are mapped as follows:

- Embedded utilities memory block (EUMBBAR contains base address) for local bus accesses. Watchpoint registers located at offsets 0xF_F018 to 0xF_F048.
- Embedded utilities peripheral control and status registers (PCSRBAR contains base address) for PCI bus accesses. Watchpoint registers located at offsets 0xF18 to 0xF48.

The offsets to individual watchpoint registers are listed in Table 16-2.

Table 16-2. Watchpoint Register Offsets

Local Bus Offset	PCI Bus Offset	Size (bytes)	Program Access Size (bytes)	Register	Register Access	Reset Value
0xF_F018	0xF18	4	4	WP1_CNTL_TRIG	R/W	0x0000_0000
0xF_F01C'	0xF1C	4	4	WP1_ADDR_TRIG	R/W	0x0000_0000
0xF_F020	0xF20	4	4	WP1_CTRL_MASK	R/W	0x0000_0000
0xF_F024	0xF24	4	4	WP1_ADDR_MASK	R/W	0x0000_0000
0xF_F030	0xF30	4	4	WP2_CNTL_TRIG	R/W	0x0000_0000
0xF_F034	0xF34	4	4	WP2_ADDR_TRIG	R/W	0x0000_0000
0xF_F038	0xF38	4	4	WP2_CTRL_MASK	R/W	0x0000_0000
0xF_F03C	0xF3C	4	4	WP2_ADDR_MASK	R/W	0x0000_0000
0xF_F048	0xF48	4	1-, 2-, or 4-	WP_CONTROL	R/W	0x1000_0000

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16.2.2 Watchpoint Trigger Registers

Watchpoint triggers are set based on a subset of the peripheral logic bus that includes the 32-bit address bus and 26 control signals. These watchpoints are compared with the values on the peripheral logic bus on every clock cycle. There are separate sets of trigger registers for watchpoints #1 and #2. These registers are read/write and initialized to 0x0000_0000 on reset.

Figure 16-2 and Figure 16-3 show the format of the watchpoint #1 and watchpoint #2 control trigger registers (WP1_CNTL_TRIG and WP2_CNTL_TRIG). Note that the format of these two registers is identical, but they are shown separately to emphasize that their location is at different offsets.

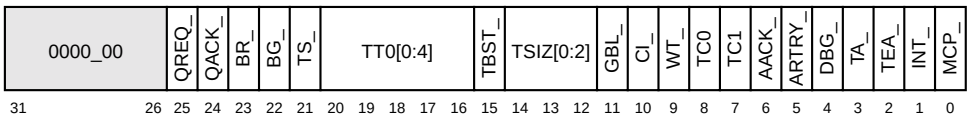

Figure 16-2. Watchpoint #1 Control Trigger Register (WP1_CNTL_TRIG)—Offsets 0xF_F018, 0xF18

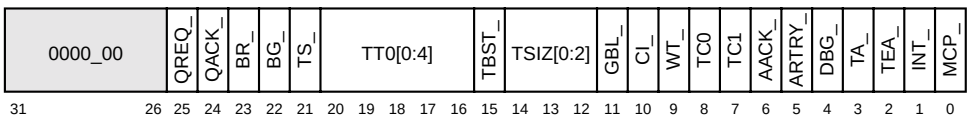

Figure 16-3. Watchpoint #1 Control Trigger Register (WP1_CNTL_TRIG)—Offsets 0xF_F030, 0xF30

Table 16-3 shows the bit definitions for WP1_CNTL_TRIG and WP2_CNTL_TRIG.

Table 16-3. Watchpoint Control Trigger Register Bit Field Definitions

Bits	Name	Reset Value	R/W	Description
31–26	—	0b000_000	R	Reserved
25	QREQ_	0	R/W	0 Trigger if $\overline{\text{QREQ}}$ asserted on peripheral logic bus 1 Trigger if $\overline{\text{QREQ}}$ negated
24	QACK_	0	R/W	0 Trigger if $\overline{\text{QACK}}$ asserted on peripheral logic bus 1 Trigger if $\overline{\text{QACK}}$ negated
23	BR_	0	RW	0 Trigger if $\overline{\text{BR}}$ asserted on peripheral logic bus 1 Trigger if $\overline{\text{BR}}$ negated
22	BG_	0	RW	0 Trigger if $\overline{\text{BG}}$ asserted on peripheral logic bus 1 Trigger if $\overline{\text{BG}}$ negated
21	TS_	0	R/W	0 Trigger if $\overline{\text{TS}}$ asserted on peripheral logic bus 1 Trigger if $\overline{\text{TS}}$ negated

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Table 16-3. Watchpoint Control Trigger Register Bit Field Definitions (Continued)

Bits	Name	Reset Value	R/W	Description
20–16	TT[0:4]	0b0_0000	R/W	Trigger match condition for TT[0:4] setting on peripheral logic bus
15	TBST_	0	R/W	0 Trigger if $\overline{\text{TBST}}$ asserted on peripheral logic bus 1 Trigger if $\overline{\text{TBST}}$ negated
14–12	TSIZ[0:2]	0b000	R/W	Trigger match condition for TSIZ[0:2] on peripheral logic bus
11	GBL_	0	R/W	0 Trigger if $\overline{\text{GBL}}$ asserted on peripheral logic bus 1 Trigger if $\overline{\text{GBL}}$ negated
10	CI_	0	R/W	0 Trigger if $\overline{\text{CI}}$ asserted on peripheral logic bus 1 Trigger if $\overline{\text{CI}}$ negated
9	WT_	0	R/W	0 Trigger if $\overline{\text{WT}}$ asserted on peripheral logic bus 1 Trigger if $\overline{\text{WT}}$ negated
8–7	TC[0:1]	0b00	RW	Trigger match condition for TC[0:1] on peripheral logic bus
6	AACK_	0	R/W	0 Trigger if $\overline{\text{AACK}}$ asserted on peripheral logic bus 1 Trigger if $\overline{\text{AACK}}$ negated
5	ARTRY_	0	R/W	0 Trigger if $\overline{\text{ARTRY}}$ asserted on peripheral logic bus 1 Trigger if $\overline{\text{ARTRY}}$ negated
4	DBG_	0	R/W	0 Trigger if $\overline{\text{DBG}}$ asserted on peripheral logic bus 1 Trigger if $\overline{\text{DBG}}$ negated
3	TA_	0	R/W	0 Trigger if $\overline{\text{TA}}$ asserted on peripheral logic bus 1 Trigger if $\overline{\text{TA}}$ negated
2	TEA_	0	R/W	0 Trigger if $\overline{\text{TEA}}$ asserted on peripheral logic bus 1 Trigger if $\overline{\text{TEA}}$ negated
1	INT_	0	R/W	0 Trigger if $\overline{\text{INT}}$ asserted on peripheral logic bus 1 Trigger if $\overline{\text{INT}}$ negated
0	MCP_	0	R/W	0 Trigger if $\overline{\text{MCP}}$ asserted on peripheral logic bus 1 Trigger if $\overline{\text{MCP}}$ negated

Figure 16-4 and Figure 16-5 show the format of the watchpoint #1 and watchpoint #2 address trigger registers (WP1_ADDR_TRIG and WP2_ADDR_TRIG). The format is identical, but they are shown separately to show the offsets.

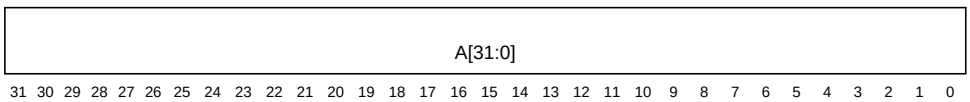

Figure 16-4. Watchpoint #1 Address Trigger Register (WP1_ADDR_TRIG)—Offsets 0xF_F01C, 0xF1C

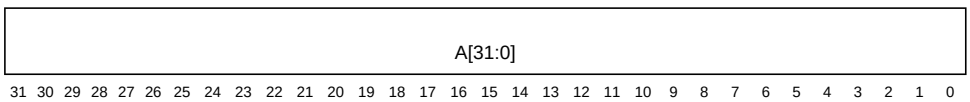

Figure 16-5. Watchpoint #2 Address Trigger Register (WP2_ADDR_TRIG)—Offsets 0xF_F034, 0xF34

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Table 16-4 shows the bit definitions for WP1_ADDR_TRIG and WP2_ADDR_TRIG.

Table 16-4. Watchpoint Address Trigger Register Bit Field Definitions

Bits	Name	Reset Value	R/W	Description
31–0	A[31:0]	all 0s	R/W	Trigger value for peripheral logic address bus

16.2.3 Watchpoint Mask Registers

The watchpoint trigger masks are bit-wise ANDed with the corresponding watchpoint trigger bits that have been compared with the current state of the peripheral logic address and control buses to detect watchpoint matches as shown in Figure 16-6. Thus, a 1 in any bit of a watchpoint mask register enables the compare of that watchpoint trigger bit and its corresponding signal on the peripheral logic; a value of zero in the mask register bit position causes that bit of the watchpoint trigger to be effectively ignored. Note that all unmasked bits in the appropriate WPx_CNTL_TRIG register must match the value on the 60x bus in order for a watchpoint match to occur.

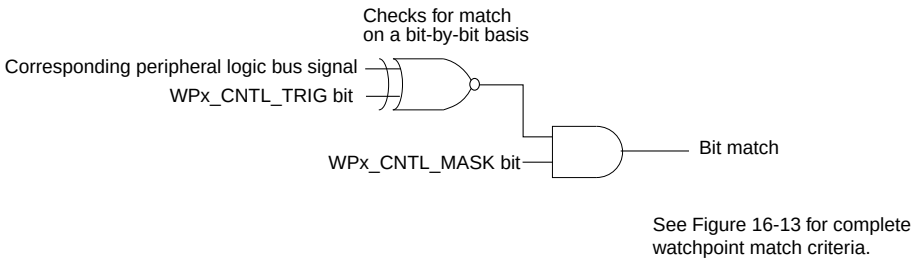

Figure 16-6. Bit Match Generation for Watchpoint Trigger Bit Settings

There are separate watchpoint trigger mask registers for both the control and address portions of watchpoint #1 and #2. These registers are read/writable and are initialized to 0x0000_0000. The format of the WP1_CNTL_MASK and WP2_CNTL_MASK registers is shown in Figure 16-7 and Figure 16-8. Note that the format of these two registers is identical, but they are shown separately to emphasize that their location is at different offsets.

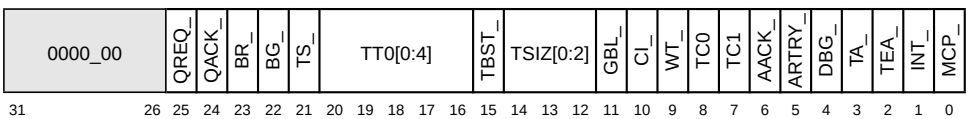

Figure 16-7. Watchpoint #1 Control Mask Register (WP1_CNTL_MASK)—Offsets 0xF_F020, 0xF20

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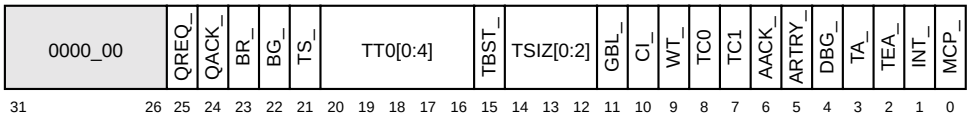

Figure 16-8. Watchpoint #2 Control Mask Register (WP2_CNTL_MASK)—Offsets 0xF_F038, 0xF38

Table 16-5 shows the bit definitions for WP1_CNTL_MASK and WP2_CNTL_MASK.

Table 16-5. Watchpoint Control Mask Register Bit Field Definitions

Bits	Name	Reset Value	R/W	Description
31–25	—	0b000_000	R	Reserved
24	QACK_	0	R/W	0 Ignore QACK_ trigger bit in WPx_CNTL_TRIG. 1 Compare $\overline{\text{QACK}}$ on peripheral logic bus with WPx_CNTL_TRIG bit.
23	BR_	0	RW	0 Ignore BR_ trigger bit in WPx_CNTL_TRIG 1 Compare $\overline{\text{BR}}$ on peripheral logic bus with WPx_CNTL_TRIG bit
22	BG_	0	RW	0 Ignore BG_ trigger bit in WPx_CNTL_TRIG 1 Compare $\overline{\text{BG}}$ on peripheral logic bus with WPx_CNTL_TRIG bit
21	TS_	0	R/W	0 Ignore TS_ trigger bit in WPx_CNTL_TRIG. 1 Compare $\overline{\text{TS}}$ on peripheral logic bus with WPx_CNTL_TRIG bit.
20–16	TT[0:4]	0b0_0000	R/W	Trigger mask for peripheral logic address transfer attribute
15	TBST_	0	R/W	0 Ignore TBST_ trigger bit in WPx_CNTL_TRIG. 1 Compare $\overline{\text{TBST}}$ on peripheral logic bus with WPx_CNTL_TRIG bit.
14–12	TSIZ[0:2]	0b000	R/W	Trigger mask for peripheral logic transfer size
11	GBL_	0	R/W	0 Ignore GBL_ trigger bit in WPx_CNTL_TRIG, 1 Compare $\overline{\text{GBL}}$ on peripheral logic bus with WPx_CNTL_TRIG bit.
10	CI_	0	R/W	0 Ignore CI_ trigger bit in WPx_CNTL_TRIG. 1 Compare $\overline{\text{CI}}$ on peripheral logic bus with WPx_CNTL_TRIG bit.
9	WT_	0	R/W	0 Ignore WT_ trigger bit in WPx_CNTL_TRIG. 1 Compare $\overline{\text{WT}}$ on peripheral logic bus with WPx_CNTL_TRIG bit.
8–7	TC[0:1]	0b00	RW	Trigger mask for peripheral logic Transfer Code
6	AACK_	0	R/W	0 Ignore AACK_ trigger bit in WPx_CNTL_TRIG. 1 Compare $\overline{\text{AACK}}$ on peripheral logic bus with WPx_CNTL_TRIG bit.
5	ARTRY_	0	R/W	0 Ignore ARTRY_ trigger bit in WPx_CNTL_TRIG. 1 Compare $\overline{\text{ARTRY}}$ on peripheral logic bus with WPx_CNTL_TRIG bit.
4	DBG_	0	R/W	0 Ignore DBG_ trigger bit in WPx_CNTL_TRIG. 1 Compare $\overline{\text{DBG}}$ on peripheral logic bus with WPx_CNTL_TRIG bit.
3	TA_	0	R/W	0 Ignore TA_ trigger bit in WPx_CNTL_TRIG. 1 Compare $\overline{\text{TA}}$ on peripheral logic bus with WPx_CNTL_TRIG bit.
2	TEA_	0	R/W	0 Ignore TEA_ trigger bit in WPx_CNTL_TRIG. 1 Compare $\overline{\text{TEA}}$ on peripheral logic bus with WPx_CNTL_TRIG bit.

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Table 16-5. Watchpoint Control Mask Register Bit Field Definitions (Continued)

Bits	Name	Reset Value	R/W	Description
1	INT_	0	R/W	0 Ignore INT_ trigger bit in WPx_CNTL_TRIG. 1 Compare $\overline{\text{INT}}$ on peripheral logic bus with WPx_CNTL_TRIG bit.
0	MCP_	0	R/W	0 Ignore MCP_ trigger bit in WPx_CNTL_TRIG. 1 Compare $\overline{\text{MCP}}$ on peripheral logic bus with WPx_CNTL_TRIG bit.

Figure 16-9 and Figure 16-10 show the format of the watchpoint #1 and watchpoint #2 address mask registers (WP1_ADDR_MASK and WP2_ADDR_MASK). The format is identical, but they are shown separately to show the offsets.

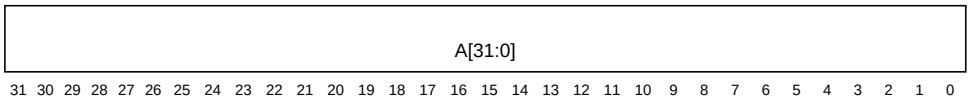

Figure 16-9. Watchpoint #1 Address Mask Register (WP1_ADDR_MASK)—Offsets 0xF_F024, 0xF24

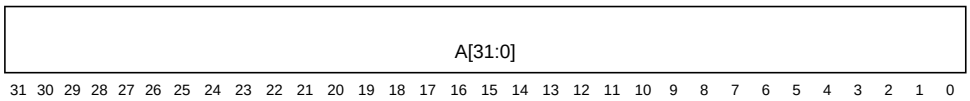

Figure 16-10. Watchpoint #2 Address Mask Register (WP2_ADDR_MASK)—Offsets 0xF_F03C, 0xF3C

Table 16-6 shows the bit field definitions for WP1_ADDR_MASK and WP2_ADDR_MASK.

Table 16-6. Watchpoint Address Mask Register Bit Field Definitions

Bits	Name	Reset Value	R/W	Description
31–0	A[31:0]	all 0s	R/W	Trigger mask for peripheral logic address bus

16.2.4 Watchpoint Control Register (WP_CONTROL)

The watchpoint control register configures the watchpoint facility. It has fields that allow the user to enable the watchpoint facility, enable the debug addresses in software, initialize the watchpoint counters, select the driver modes for TRIG_OUT, and set the watchpoint mode of operation. Figure 16-11 shows the format of WP_CONTROL.

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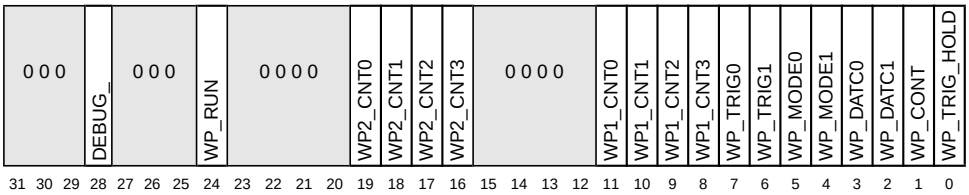

Figure 16-11. Watchpoint Control Register (WP_CONTROL)— Offsets 0xF_F048, 0xF48

Table 16-7 shows the bit field definitions for WP_CONTROL.

Table 16-7. Watchpoint Control Register Bit Field Definitions

Bits	Name	Reset Value	R/W	Description
31–29	—	0b000	R	Reserved
28	DEBUG_ADDR_	x	RW	Debug address disable. See Section 15.3, “Memory Debug Address,” for more information. 0 Debug address facility is enabled 1 Debug address facility is disabled Note that the reset value of this bit is determined by the $\overline{\text{GNT4}}$ signal. See Section 2.4, “Configuration Signals Sampled at Reset,” for more information.
27–25	—	0b000	R	Reserved
24	WP_RUN	0	R/W	The watchpoint run bit is used to start and stop a watchpoint scan. This is the only watchpoint register bit that should be changed by software while the watchpoint facility is enabled (WP_RUN = 1). This bit can also be toggled externally by pulsing the TRIG_IN signal if the watchpoint facility is not in the HOLD state. When the watchpoint facility is in the HOLD state, pulsing TRIG_IN causes the watchpoint facility to wake up and continue or conclude its scan as programmed. 0 Start a watchpoint scan. 1 Stop a watchpoint scan.
23–20	—	0b0000	R	Reserved
19–16	WP2_CNT[0–3]	0b0000	R/W	The watchpoint #2 counter field sets the initial value of the countdown counter for watchpoint #2. This counter is only used in watchpoint waterfall mode (WP_MODE = 0b01). 0000 16 0001 1 0010 2 ... 1111 15
15–12	—	0b0000	R	Reserved

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Table 16-7. Watchpoint Control Register Bit Field Definitions (Continued)

Bits	Name	Reset Value	R/W	Description
11–8	WP1_CNT[0–3]	0b0000	R/W	The watchpoint #1 counter field sets the initial value of the countdown counter for watchpoint #1. This counter is used in all watchpoint operation modes. 0000 16 0001 1 0010 2 ... 1111 15
7–6	WP_TRIG[0–1]	0b00	R/W	The watchpoint trigger control field is used to select the driver modes of the TRIG_OUT signal as follows: 0x TRIG_OUT is disabled; TRIG_OUT is in high-impedance state. 10 TRIG_OUT is enabled as an active high output. 11 TRIG_OUT is enabled as an active low output.
5–4	WP_MODE[0–1]	0b00	R/W	The watchpoint mode field is used to define the operation modes of the watchpoint facility. The supported functions are described in Table 16-8.
3–2	—	0b00	R	Reserved
1	WP_CONT	0	R/W	The watchpoint continuous scan bit selects between continuous scan mode and one-shot scan mode. In continuous mode, the watchpoint facility continuously scans for trigger matches. Upon each occurrence of a trigger match, the watchpoint facility issues an output trigger (if programmed to do so) and begins a new scan for the next trigger match. The watchpoint facility continues to generate multiple output triggers until the watchpoint facility is explicitly disabled by the user by writing WP_RUN =0. In one-shot scan mode, the watchpoint facility scans for the first trigger match. Upon the first occurrence of the trigger match, the watchpoint facility issues an output trigger (if programmed to do so and automatically disables the watchpoint facility by writing WP_RUN = 0. Further trigger matches will not generate output triggers until the watchpoint facility is re-enabled by the setting of WP_RUN = 1 or the assertion of TRIG_IN. 0 One-shot scan mode 1 Continuous scan mode
0	WP_TRIG_HOLD	0	R/W	Trigger hold enable. When trigger hold mode is enabled, the watchpoint facility enters a HOLD state upon a trigger match. Additionally, the TRIG_OUT signal remains asserted while the watchpoint facility remains in the HOLD state. The watchpoint facility can be resumed from this HOLD state by pulsing TRIG_IN. Pulsing the TRIG_IN signal while in the HOLD state does not toggle the WP_RUN bit. 0 Trigger hold disabled 1 Trigger hold enabled

Table 16-8 describes the modes selected by the WP_MODE field of the WP_CONTROL register.

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Table 16-8. Watchpoint Mode Select (WP_CONTROL[WP_MODE])

WP_MODE [0–1]	Definition	Watchpoint #1 Trigger (T_1)	Watchpoint #1 Counter (C_1)	Watchpoint #2 Trigger (T_2)	Watchpoint #2 Counter (C_2)
00	Single mode Assert TRIG_OUT after C_1th occurrence of the unmasked trigger parameters for watchpoint #1.	√	√	n/a	n/a
01	Waterfall mode Scan for C_1th occurrence of the unmasked trigger parameters for watchpoint #1 and then assert TRIG_OUT after the C_2th occurrence of the unmasked trigger parameters for watchpoint #2.	√	√	√	√
10	OR mode Assert TRIG_OUT after C_1th occurrence of the unmasked trigger parameters for watchpoint #1 OR any occurrence of the unmasked trigger parameters for watchpoint #2.	√	√	√	n/a
11	AND NOT mode Assert TRIG_OUT after C_1th occurrence of the unmasked trigger parameters for watchpoint #1 AND NOT any occurrence of the unmasked trigger parameters for watchpoint #2.	√	√	√	n/a

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16.3 State and Block Diagrams

Figure 16-12 shows a state diagram of the watchpoint facility.

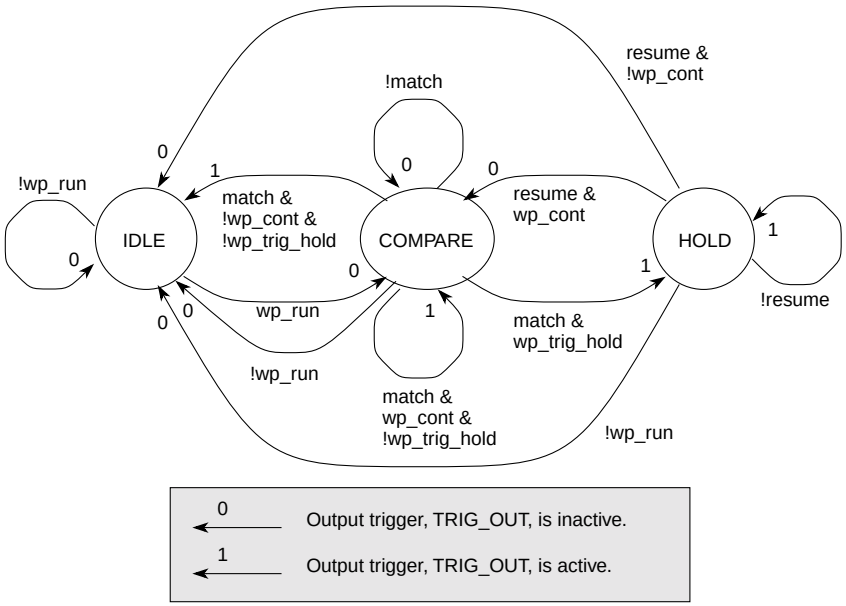

Figure 16-12. Watchpoint Facility State Diagram

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Figure 16-13 shows a block diagram of the watchpoint facility.

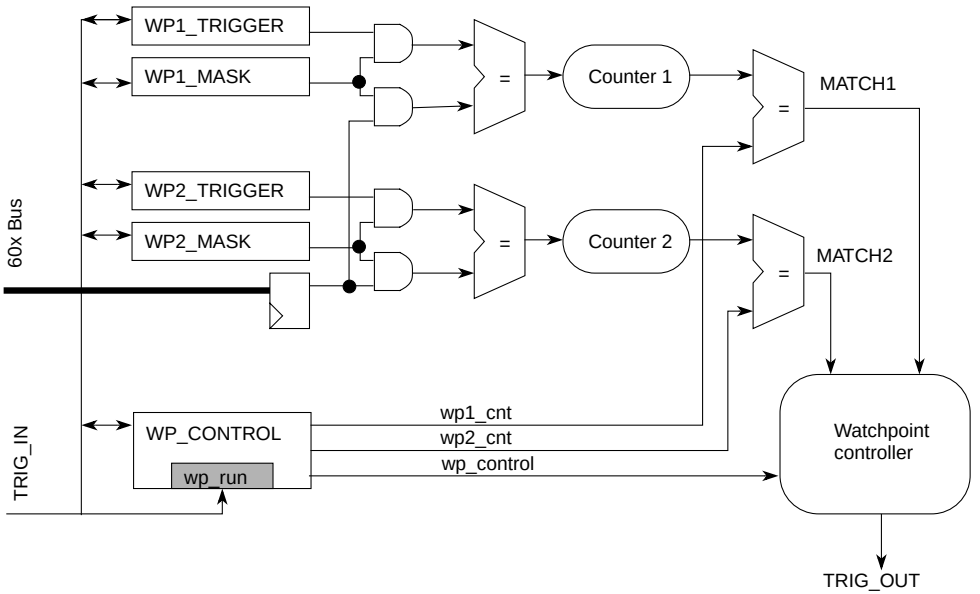

Figure 16-13. Watchpoint Facility Block Diagram

16.4 Watchpoint Trigger Applications

The watchpoint facility output trigger can be used by the system designer to initiate a halt to the processor core through the checkstop signals. When the processor clock is stopped, the internal state of the processor can then be scanned out through the JTAG port (TDO) using emulators available from third party tool developers.

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Appendix A
Address Map A

The MPC8240 supports two address maps. The preferred address map, map B, is described in Chapter 3, “Address Maps.” This appendix describes address map A.

Address map A conforms to the now-obsolete PowerPC reference platform (PReP) specification. Support for address map A is provided solely for backward compatibility with MPC106-based systems that used the PReP address map. It is strongly recommended that new designs use map B and existing designs be revised to use map B because map A may not be supported in future devices.

A.1 Address Space for Map A

The address space of map A is divided into four areas—local memory, PCI I/O, PCI memory, and system ROM space. Table A-1, Figure A-2, and Table A-3 show separate views of address map A for the processor core, a PCI memory device, and a PCI I/O device, respectively. When configured for map A, the MPC8240 translates addresses across the internal peripheral logic bus and the external PCI bus as shown in Figure A-1 through Figure A-3.

Table A-1. Address Map A—Processor View

Processor Core Address Range				PCI Address Range	Definition
Hex		Decimal			
0000_0000	3FFF_FFFF	0	1G - 1	No PCI cycle	Local memory space
4000_0000	7FFF_FFFF	1G	2G - 1	No PCI cycle	Reserved
8000_0000	807F_FFFF	2G	2G + 8M - 1	0000_0000–007F_FFFF	PCI I/O space[1,2]
8080_0000	80FF_FFFF	2G + 8M	2G + 16M - 1	0080_0000–00FF_FFFF	PCI configuration direct access[3]
8100_0000	BF7F_FFFF	2G + 16M	3G - 8M - 1	0100_0000–3F7F_FFFF	PCI I/O space
BF80_0000	BFFF_FFEF	3G - 8M	3G - 16 - 1	3F80_0000–3FFF_FFEF	Reserved
BFFF_FFF0	BFFF_FFFF	3G - 16	3G - 1	3FFF_FFF0–3FFF_FFFF	PCI interrupt acknowledge
C000_0000	FEFF_FFFF	3G	4G - 16M - 1	0000_0000–3EFF_FFFF	PCI memory space
FF00_0000	FFFF_FFFF	4G - 16M	4G - 1	FF00_0000–FFFF_FFFF[4]	ROM space[4]

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Table A-2. Map A—PCI Memory Master View

PCI Memory Transactions Address Range				Processor Core Address Range	Definition
Hex		Decimal			
0000_0000	7FFF_FFFF	0	2G - 1	No local memory cycle	PCI memory space
8000_0000	BFFF_FFFF	2G	3G - 1	0000_0000–3EFF_FFFF	Local memory space
C000_0000	FEFF_FFFF	3G	4G - 16M - 1	No local memory cycle	Reserved (causes memory select error)
FF00_0000	FFFF_FFFF	4G - 16M	4G - 1	No local memory cycle	ROM space (reserved if ROM is local)[5]

Table A-3. Address Map A—PCI I/O Master View

PCI I/O Transactions Address Range				Processor Core Address Range	Definition
Hex		Decimal			
0000_0000	0000_FFFF	0	64K - 1	No local memory cycle	Addressable by the processor
0001_0000	007F_FFFF	64K	8M - 1	No local memory cycle	Reserved[2]
0080_0000	3F7F_FFFF	8M	1G - 8M - 1	No local memory cycle	Addressable by the processor
3F80_0000	3FFF_FFFF	1G - 8M	1G - 1	No local memory cycle	Not addressable by the processor
4000_0000	FFFF_FFFF	1G	4G - 1	No local memory cycle	Not addressable by the processor

Notes:

1 PCI configuration accesses to CF8 and CFC–CFF are handled as specified in the PCI Local Bus Specification. See Section 7.4.5.2, “Accessing the PCI Configuration Space,” for more information on how the MPC8240 accesses PCI configuration space.

2. Processor addresses are translated to PCI addresses as follows:
PCI address (AD[31:0]) = 0b0 || A[1:31]. PCI configuration accesses use processor addresses 0x8000_0CF8 and 0x8000_0CFC–8000_0CFF.
Note that only 64 Kbytes (0x8000_0000–0x8000_FFFF) has been defined. The remainder of the region is reserved for future use.

3. IDSEL for direct access method: 11 = 0x8080_08xx, 12 = 0x8080_10xx,..., 18 = 0x8084_00xx. See Section 7.4.5.2, “Accessing the PCI Configuration Space.”

4. If the ROM is local, the MPC8240 ROM interface handles the access to local ROM. If ROM is remote, then the MPC8240 generates a PCI memory transaction in the range 0xFF00_0000 to 0xFFFF_FFFF.

5. If the ROM is local, this space is reserved and accesses to it cause a memory select/Flash write error. If the ROM is remote, then this space maps to PCI memory space.

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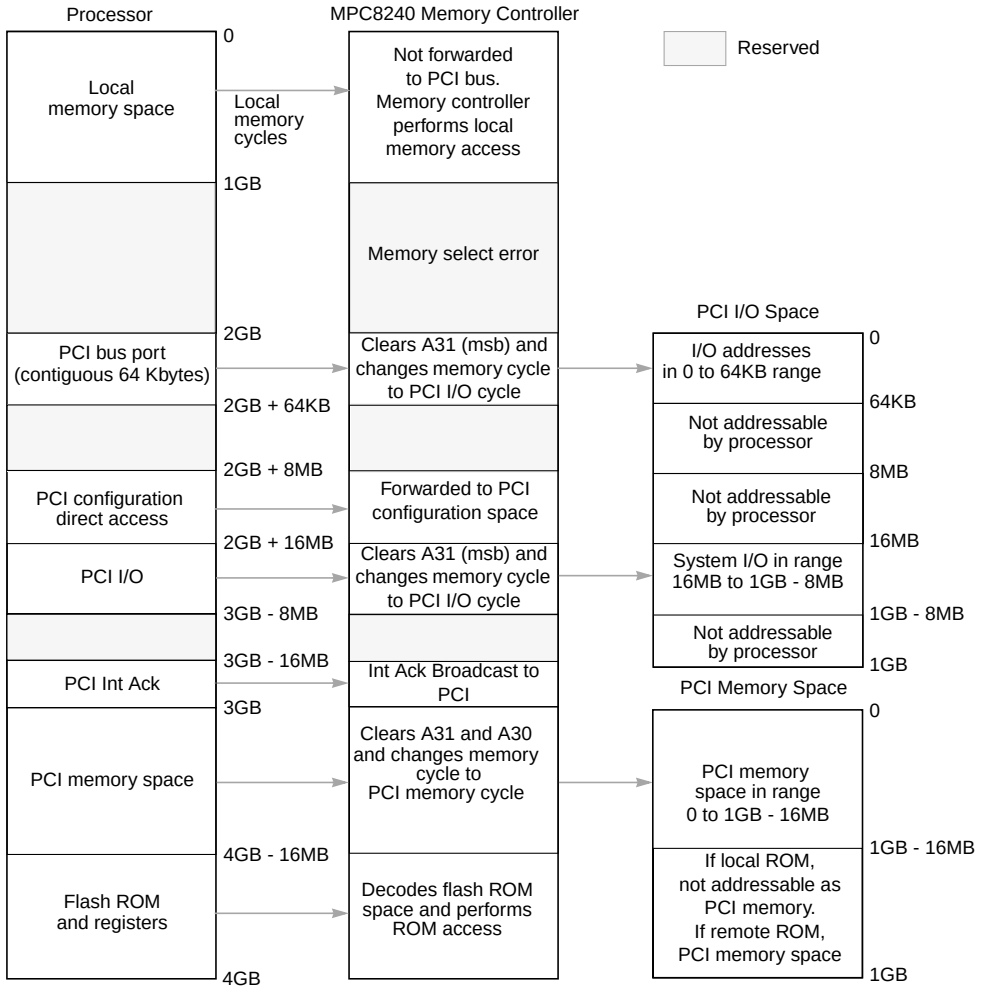
Processor
MPC8240 Memory Controller
Reserved
Local memory space
Local memory cycles
Not forwarded to PCI bus. Memory controller performs local memory access
0
1GB
Memory select error
2GB
PCI bus port (contiguous 64 Kbytes)
Clears A31 (msb) and changes memory cycle to PCI I/O cycle
2GB + 64KB
2GB + 8MB
PCI configuration direct access
Forwarded to PCI configuration space
2GB + 16MB
PCI I/O
Clears A31 (msb) and changes memory cycle to PCI I/O cycle
3GB - 8MB
3GB - 16MB
PCI Int Ack
Int Ack Broadcast to PCI
3GB
PCI memory space
Clears A31 and A30 and changes memory cycle to PCI memory cycle
4GB - 16MB
Flash ROM and registers
Decodes flash ROM space and performs ROM access
4GB
PCI I/O Space
I/O addresses in 0 to 64KB range
0
64KB
Not addressable by processor
8MB
Not addressable by processor
16MB
System I/O in range 16MB to 1GB - 8MB
1GB - 8MB
Not addressable by processor
1GB
PCI Memory Space
PCI memory space in range 0 to 1GB - 16MB
0
1GB - 16MB
If local ROM, not addressable as PCI memory. If remote ROM, PCI memory space
1GB

Figure A-1. Processor Core Address Map A

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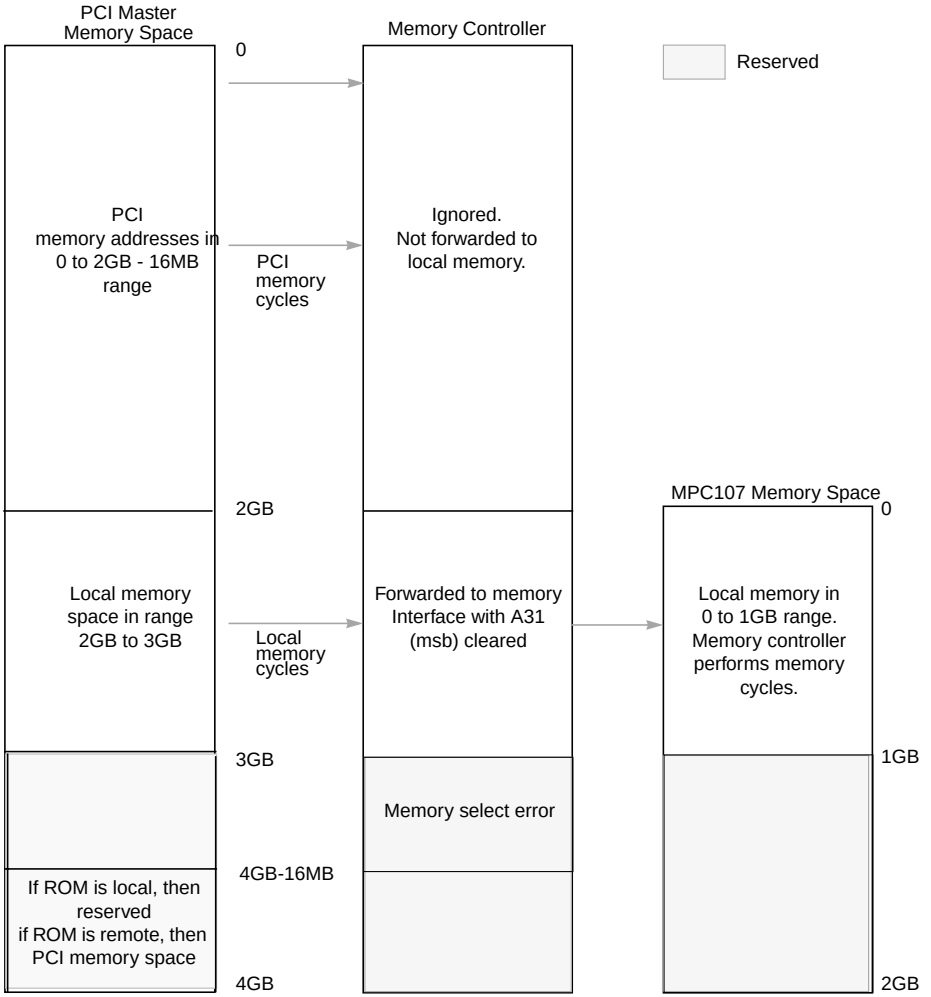

Figure A-2. PCI Memory Master Address Map A

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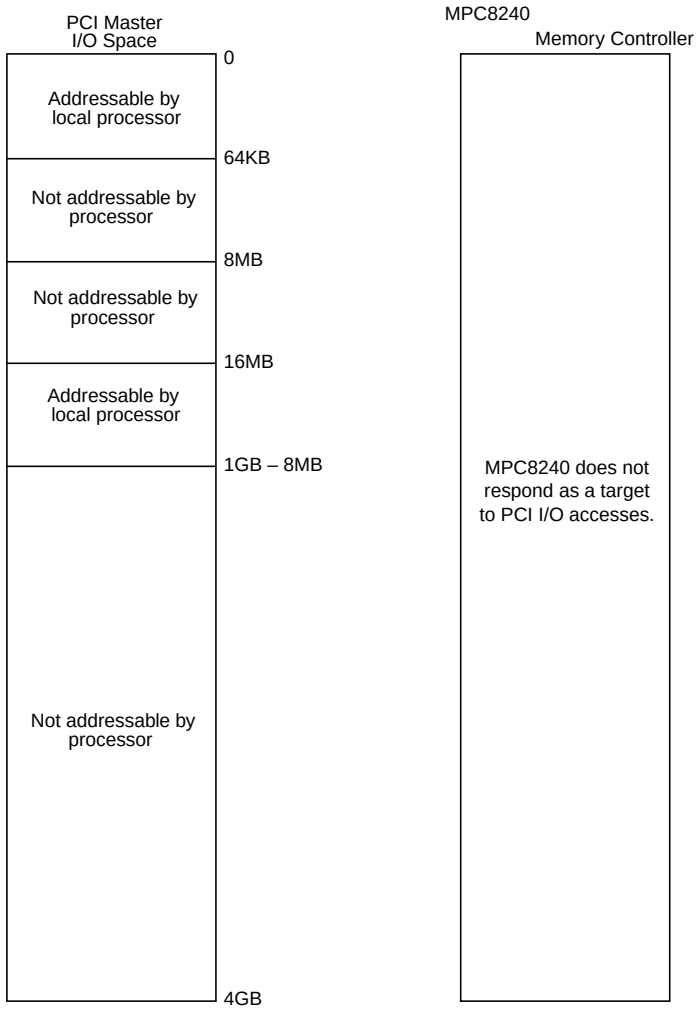

Figure A-3. PCI I/O Master Address Map A

A.2 Configuration Accesses Using Direct Method

For systems implementing address map A on the MPC8240, there is an alternate method for generating type 0 configuration cycles called the direct access method. For more information about other configuration accesses, see Section 7.4.5.2, “Accessing the PCI Configuration Space.” The direct access configuration method bypasses the CONFIG_ADDR translation step as shown in Figure A-4.

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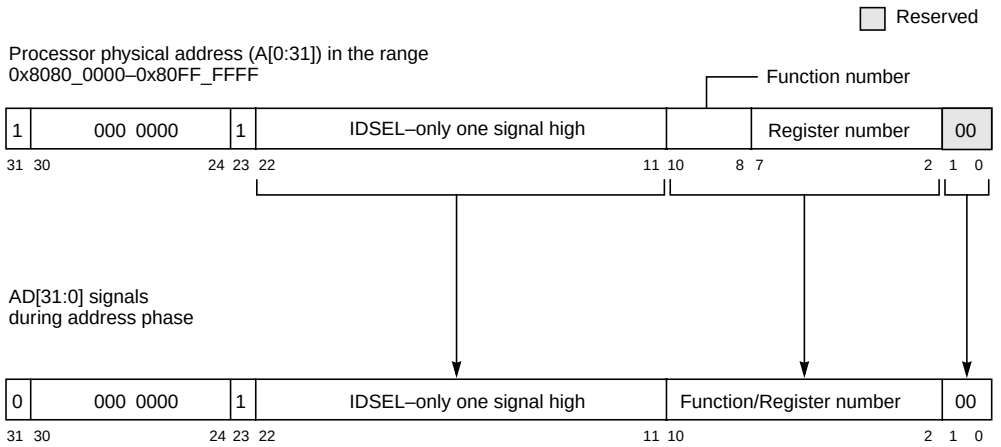

Figure A-4. Direct-Access PCI Configuration Transaction

During the address phase of a PCI configuration cycle, the MPC8240 decodes transactions from the processor core in the address range from 0x8080_0000–0x80FF_FFFF, clears the most-significant address bit, and copies the 30 low-order bits of the physical address (without modification) onto the AD[31:0] signals. The two least-significant bits of the internal peripheral logic bus address, A[30:31], must be 0b00. Note that the direct-access method is limited to generating IDSEL on AD[11:22]. Also note that AD23 is always driven high for direct-access configuration cycles. Therefore, no PCI device should use AD23 for the IDSEL input on systems using address map A.

For type 1 translations, the MPC8240 copies the 30 high-order bits of the CONFIG_ADDR register (without modification) onto the AD[31:2] signals during the address phase. The MPC8240 automatically translates AD[1:0] into 0b01 during the address phase to indicate a type 1 configuration cycle.

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Appendix B
Bit and Byte Ordering

The MPC8240 supports two byte-ordering conventions for the PCI bus and local memory—big-endian and little-endian. This appendix describes both modes and provides examples of each. Chapter 3, "Operand Conventions," in *PowerPC Microprocessor Family: The Programming Environments for 32-bit Microprocessors*, provides a general overview of byte ordering and describes byte ordering for PowerPC microprocessors.

B.1 Byte Ordering Overview

For big-endian data, the MSB is stored at the lowest (or starting) address and the LSB at the highest (or ending) address. This is called big-endian because the big (most-significant) end of the scalar comes first in memory.

For true little-endian byte ordering, the LSB is stored at the lowest address and the MSB at the highest address. This is called true little-endian because the little (least-significant) end of the scalar comes first in memory.

For PowerPC little-endian byte ordering (also referred to as munged little-endian), the address of data is modified so that the memory structure appears to be little-endian to the executing processor when, in fact, the byte ordering is big-endian. The address modification is called munging. Note that the term 'munging' is not defined or used in the PowerPC architecture specification but is commonly used to describe address modifications. The byte ordering is called PowerPC little-endian because PowerPC microprocessors use this method to operate in little-endian mode.

In addition, the PCI bus uses a bit format where the most-significant bit (msb) for data is AD31, while the processor core and the internal peripheral logic data bus use a bit format where the msb is DH0. Thus, PCI data bit AD31 equates to the processor's data bits DH0 and DL0, while PCI data bit AD0 equates to the processor's data bits DH31 and DL31.

B.2 Byte-Ordering Mechanisms

The byte-ordering mechanisms in the MPC8240 are controlled by programmable parameters. The PowerPC architecture defines two bits in a processor's machine state register (MSR) for specifying byte ordering—LE (little-endian mode) and ILE (exception little-endian mode). For the MPC8240, these bits control only the addresses generated by

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the PowerPC core. The LE bit specifies the endian mode for normal core operation and ILE specifies the mode to be used when an exception handler is invoked. That is, when an exception occurs, the ILE bit (as set for the interrupted process) is copied into MSR[LE] to select the endian mode for the context established by the exception. The LE and ILE bits control a 3-bit address modifier in the processor core.

To convert from PowerPC little-endian to true little-endian byte ordering, all the byte lanes must be reversed (MSB to LSB, and so on) and the addresses must be unmunged external to the processor core. When configured for little-endian mode, the MPC8240 unmunges the address and reverses the byte lanes between the PCI bus and local memory in the central control unit (CCU). This means that the data in local memory is stored using PowerPC little-endian byte ordering, but data on the PCI bus is in true little-endian byte order. The PICR1[LE_MODE] parameter controls a 3-bit address modifier and byte lane swapper in the CCU.

Note that the processor core and the CCU should be set for the same endian mode before accessing devices on the PCI bus.

B.3 Big-Endian Mode

When the processor core is operating in big-endian mode, no address modification is performed by the processor. In big-endian mode, the MPC8240 maintains the big-endian byte ordering on the PCI bus during the data phase(s) of PCI transactions. The byte lane translation for big-endian mode is shown in Table B-1. Note that the bit ordering on the PCI bus remains unchanged (that is, AD31 is still the msb of the byte in byte lane 3 and AD0 is still the lsb of the byte in byte lane 0).

Table B-1. Byte Lane Translation in Big-Endian Mode

Processor Byte Lane	Processor Data Bus Signals	PCI Byte Lane	PCI Address/Data Bus Signals During PCI Data Phase
0	DH[0–7]	0	AD[7–0]
1	DH[8–15]	1	AD[15–8]
2	DH[16–23]	2	AD[23–16]
3	DH[24–31]	3	AD[31–24]
4	DL[0–7]	0	AD[7–0]
5	DL[8–15]	1	AD[15–8]
6	DL[16–23]	2	AD[23–16]
7	DL[24–31]	3	AD[31–24]

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Figure B-1 shows a 4-byte write to PCI memory space in big-endian mode.

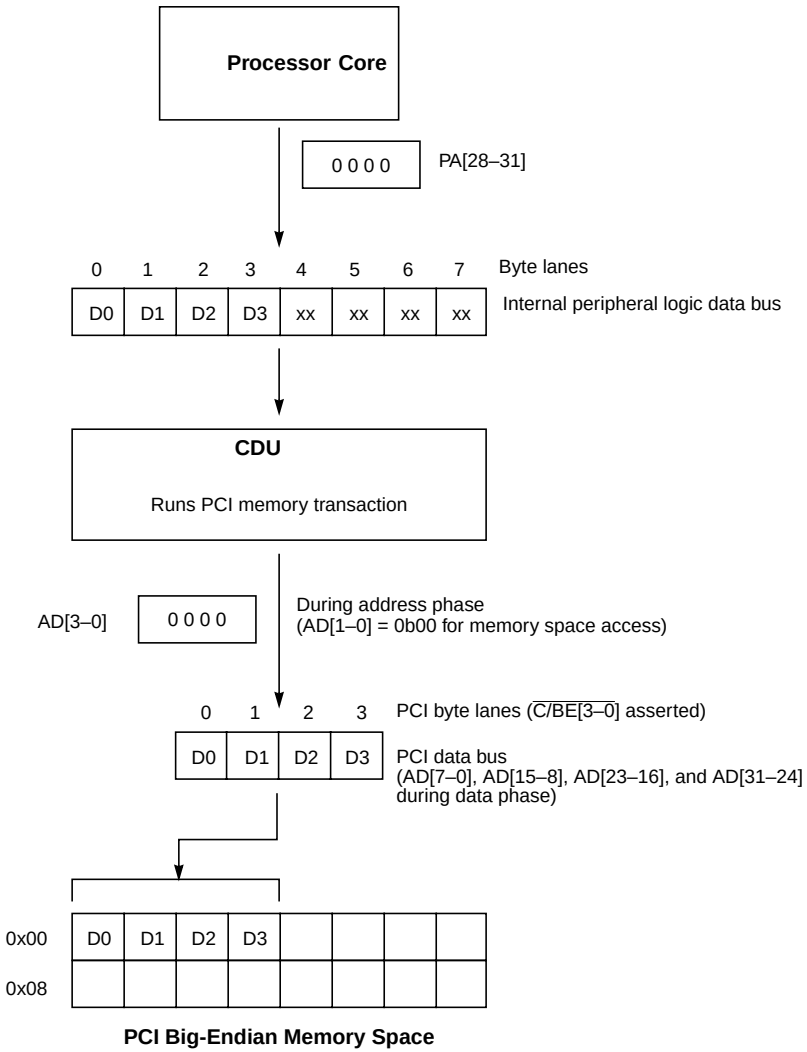

Figure B-1. Four-Byte Transfer to PCI Memory Space—Big-Endian Mode

Note that the MSB on the internal peripheral logic bus, D0, is placed on byte lane 0 (AD[7–0]) on the PCI bus. This occurs so D0 appears at address 0x*nnnn_nn*00 and not at address 0x*nnnn_nn*03 in the PCI space.

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The following example demonstrates the operation of a system in big-endian mode starting with a program that does the following:

```
store string (“hello, world”) at 0x000
store pointer (0xFEDCBA98) at 0x010
store half word (0d1234) at 0x00E
store byte (0x55) at 0x00D
```

If the data is stored into local memory, it appears as shown in Figure B-2.

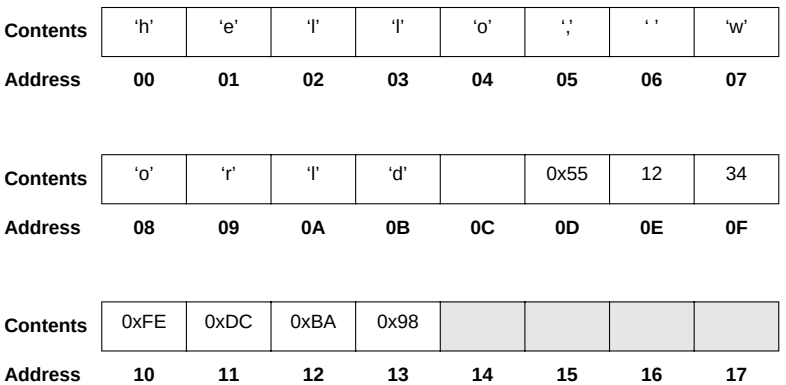

Figure B-2. . Big-Endian Memory Image in Local Memory

Note that the stored data has big-endian ordering. The ‘h’ is at address 0x000.

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If the data is stored to the PCI memory space, it appears as shown in Figure B-3.

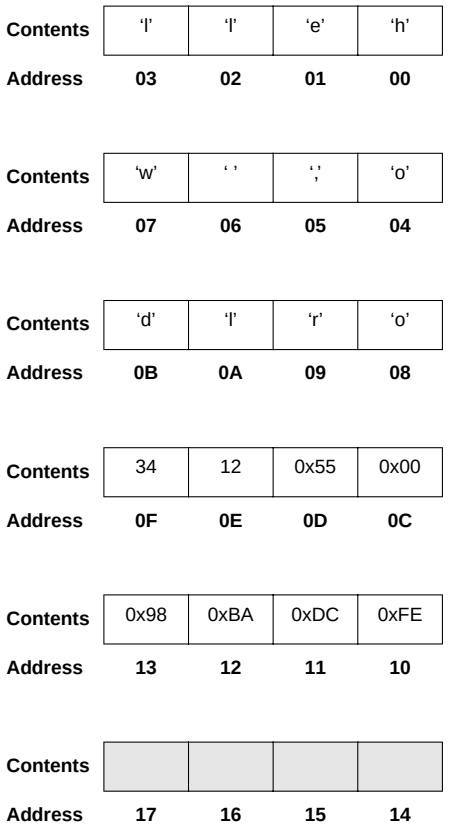

Figure B-3. Big-Endian Memory Image in Big-Endian PCI Memory Space

Note that the string 'hello, world' starts at address 0x000. The other data is stored to the desired location with big-endian byte ordering.

B.4 Little-Endian Mode

When the processor core is operating in little-endian mode, its internal BIU modifies each address. This modification is called munging. The processor munges the address by exclusive-ORing (XOR) the three low-order address bits with a three-bit value that depends on the length of the operand (1, 2, 4, or 8 bytes), as shown in Table B-2.

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Table B-2. Processor Address Modification for Individual Aligned Scalars

Data Length (in Bytes)	Address Modification A[29–31]
8	No change
4	XOR with 0b100
2	XOR with 0b110
1	XOR with 0b111

Note that munging makes individually aligned scalars appear to the processor as stored in little-endian byte order when, in fact, they are stored in big-endian order but at different byte addresses within double words. Only the address is modified not the byte order.

The munged address is used by the memory interface of the MPC8240 to access local memory. To provide true little-endian byte-ordering to the PCI bus, the MPC8240 unmunges the address to its original value and the byte lanes are reversed. The MPC8240 unmunges aligned addresses by XORing the three low-order address bits with a three-bit value that depends on the length of the operand (1, 2, 3, 4, or 8 bytes), as shown in Table B-3.

Table B-3. MPC8240 Address Modification for Individual Aligned Scalars

Data Length (in Bytes)	Address Modification A[29–31]
8	No change
4	XOR with 0b100
3	XOR with 0b101
2	XOR with 0b110
1	XOR with 0b111

The MPC8240 also supports misaligned 2-byte transfers that do not cross word boundaries in little-endian mode. The MPC8240 XORs the address with 0x100. Note that the MPC8240 does not support 2-byte transfers that cross word boundaries in little-endian mode.

The byte lane translation for little-endian mode is shown in Table B-4.

Table B-4. Byte Lane Translation in Little-Endian Mode

Processor Byte Lane	Processor Data Bus Signals	PCI Byte Lane	PCI Address/Data Bus Signals During PCI Data Phase
0	DH[0–7]	3	AD[31–24]
1	DH[8–15]	2	AD[23–16]
2	DH[16–23]	1	AD[15–8]
3	DH[24–31]	0	AD[7–0]

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Table B-4. Byte Lane Translation in Little-Endian Mode (Continued)

Processor Byte Lane	Processor Data Bus Signals	PCI Byte Lane	PCI Address/Data Bus Signals During PCI Data Phase
4	DL[0–7]	3	AD[31–24]
5	DL[8–15]	2	AD[23–16]
6	DL[16–23]	1	AD[15–8]
7	DL[24–31]	0	AD[7–0]

Starting with the same program as before:

```
store string (“hello, world”) at 0x000
store pointer (0xFEDCBA98) at 0x010
store half word (0d1234) at 0x00E
store byte (0x55) at 0x00D
```

If the data is stored to local memory in little-endian mode, the MPC8240 stores the data to the munged addresses in local memory as shown in Figure B-4.

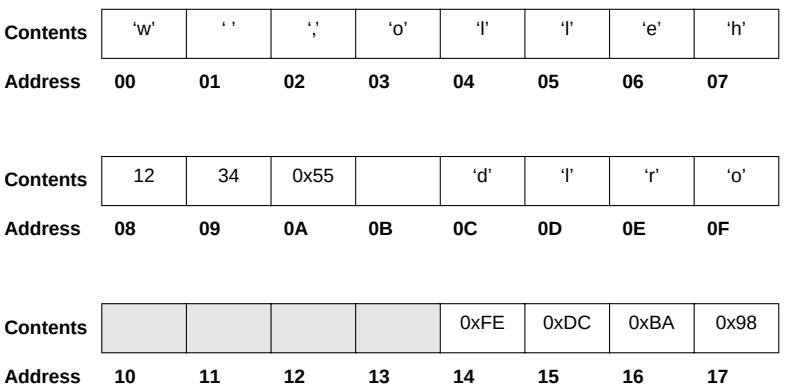

Figure B-4. Munged Memory Image in Local Memory

The image shown in Figure B-4 is not a true little-endian mapping. Note how munging has changed the addresses of the data. The ‘h’ is now at address 0x007. Also note that the byte ordering of the 4-byte pointer, 0xFEDCBA98, is big-endian; only the address has been modified. However, since the processor core munges the address when accessing local memory, the mapping appears little-endian to the processor core.

If the data is stored to the PCI memory space, or if a PCI agent reads from local memory, the MPC8240 unmunges the addresses and reverses the byte-ordering before sending the data out to the PCI bus. The data is stored to little-endian PCI memory space as shown in Figure B-5.

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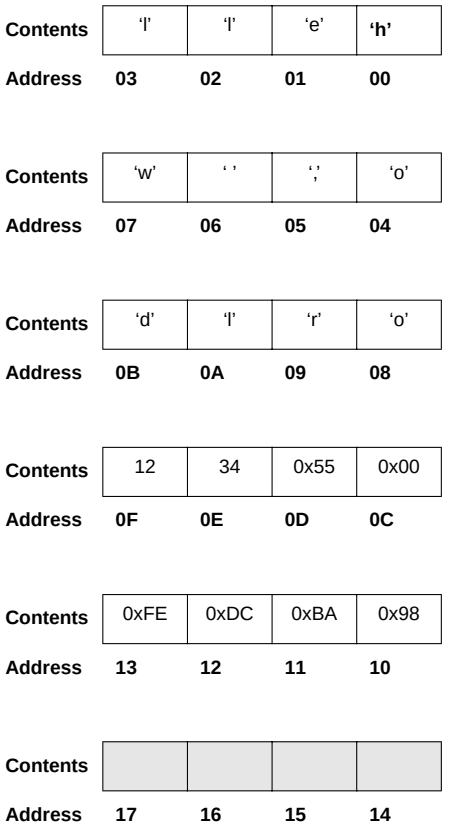

Figure B-5. Little-Endian Memory Image in Little-Endian PCI Memory Space

Note that the string 'hello, world' starts at address 0x000. The other data is stored to the desired location with true little-endian byte ordering.

Figure B-6 through Figure B-11 show the munging/unmunging process for transfers to the PCI memory space and to the PCI I/O space.

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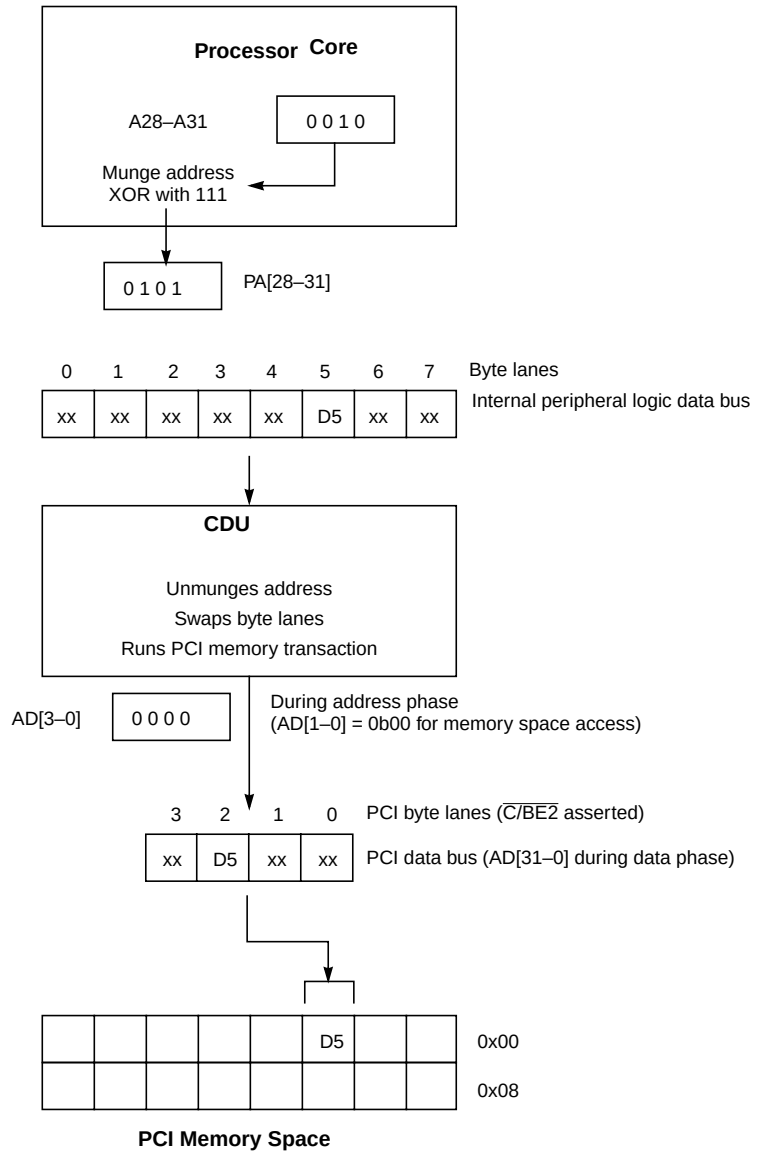

Figure B-6. One-Byte Transfer to PCI Memory Space—Little-Endian Mode

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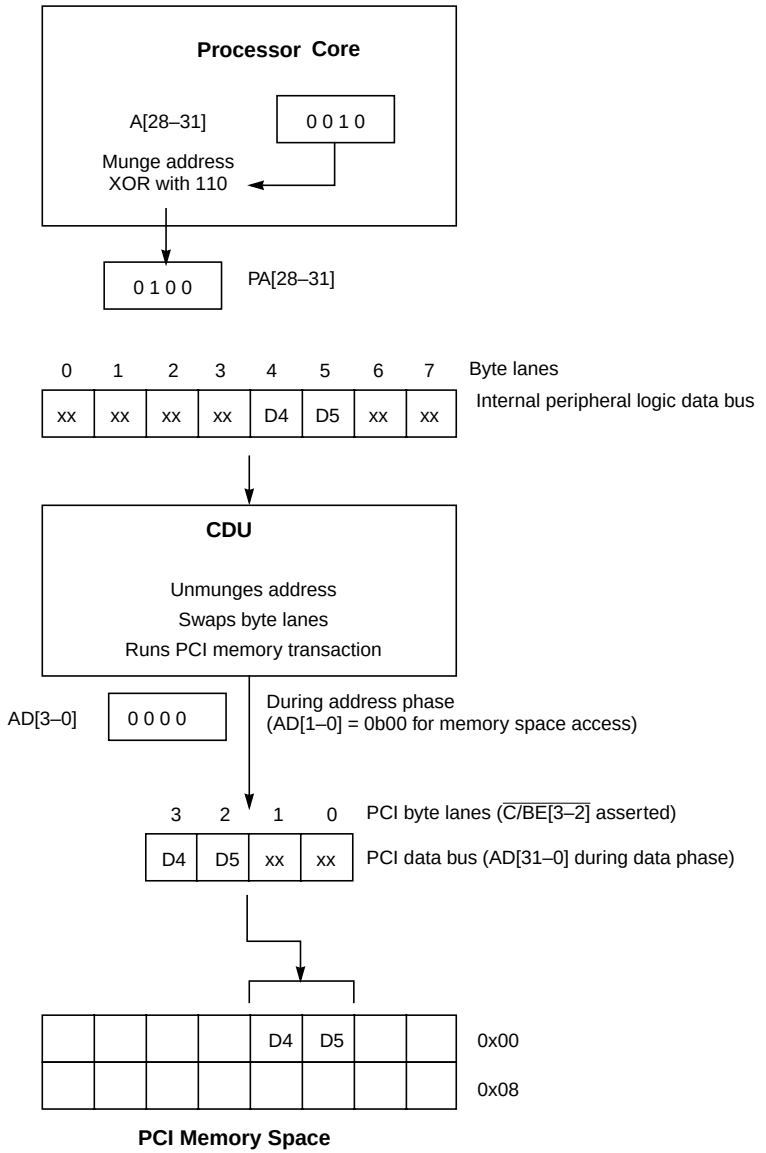

Figure B-7. Two-Byte Transfer to PCI Memory Space—Little-Endian Mode

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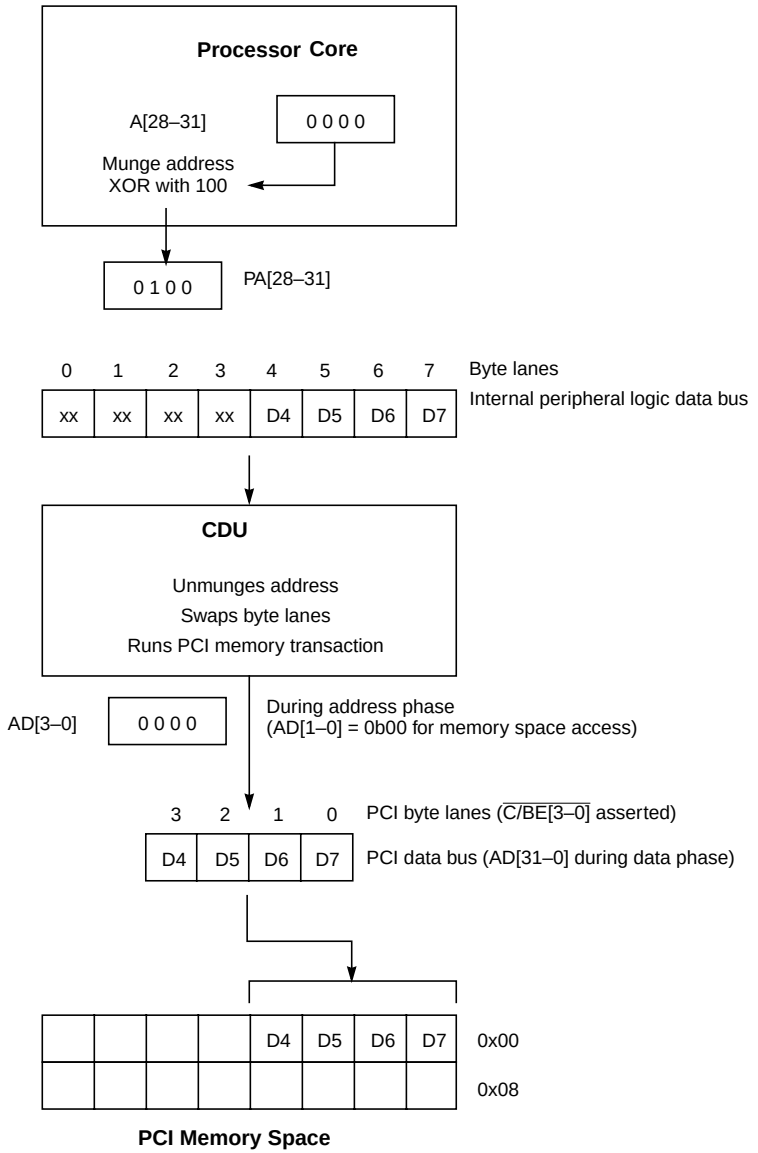

Figure B-8. Four-Byte Transfer to PCI Memory Space—Little-Endian Mode

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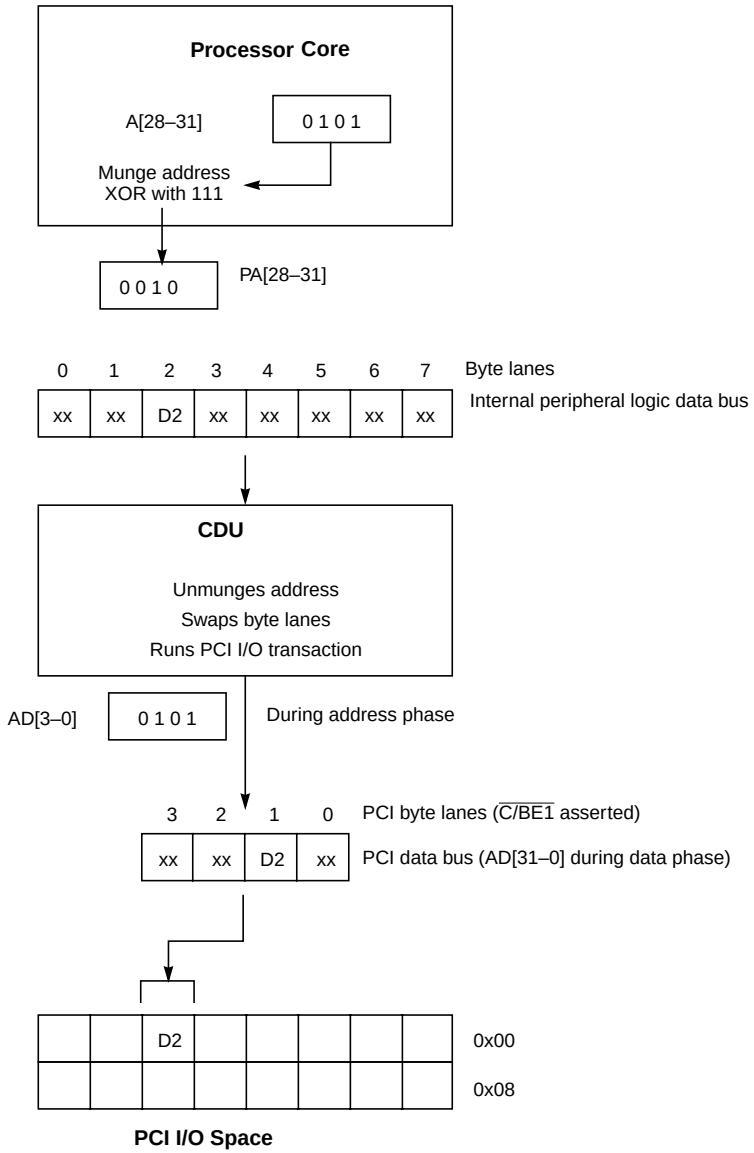

Figure B-9. One-Byte Transfer to PCI I/O Space—Little-Endian Mode

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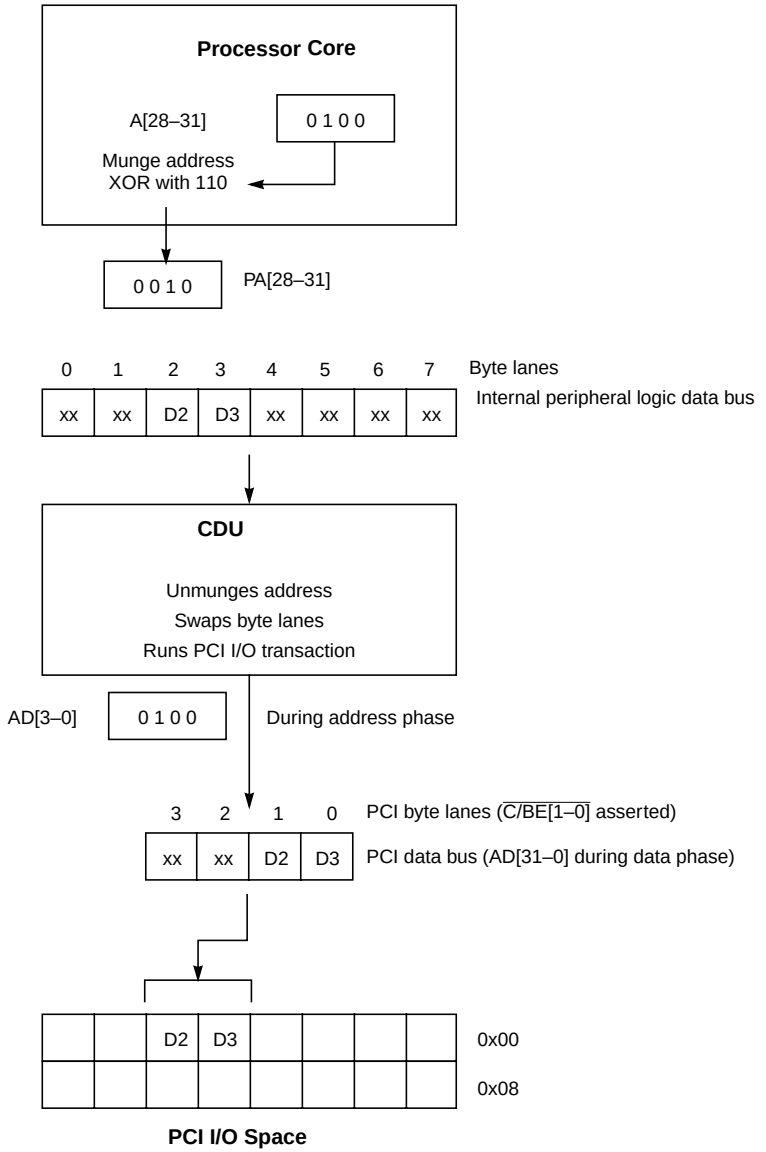

Figure B-10. Two-Byte Transfer to PCI I/O Space—Little-Endian Mode

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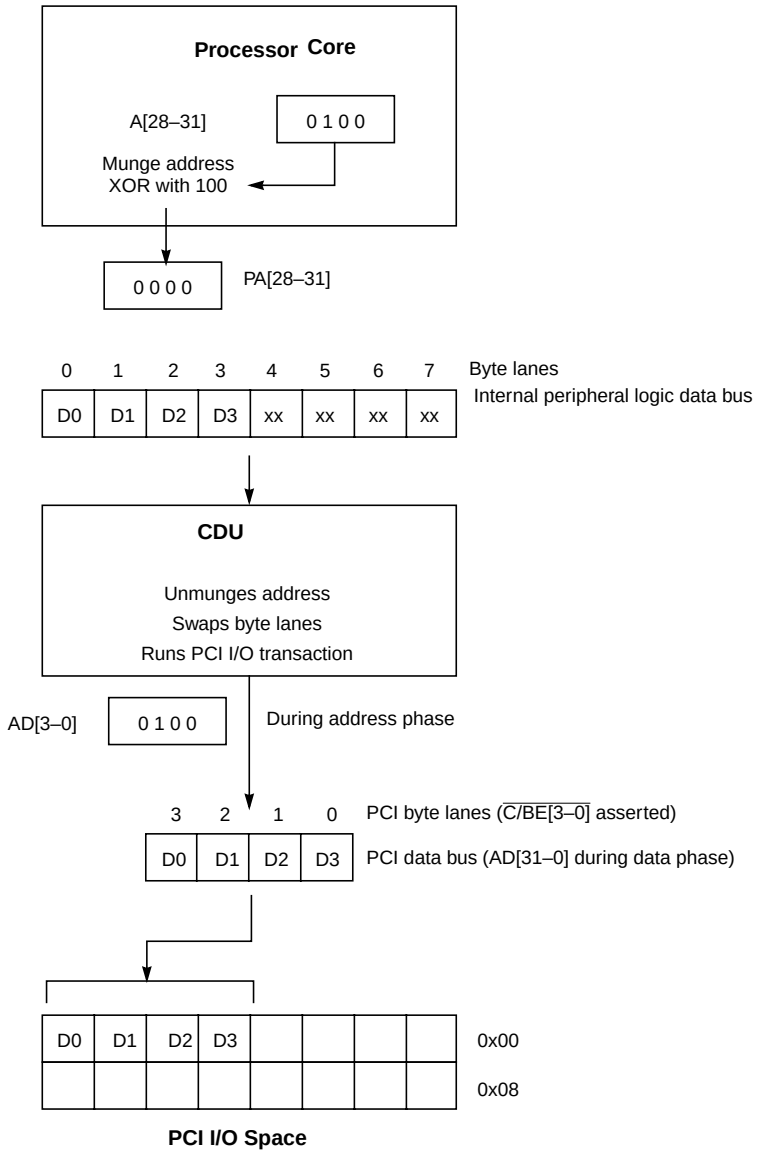

Figure B-11. Four-Byte Transfer to PCI I/O Space—Little-Endian Mode

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B.4.1 I/O Addressing in Little-Endian Mode

For a system running in big-endian mode, both the processor core and the memory subsystem recognize the same byte as byte 0. However, this is not true for a system running in little-endian mode because of the munged address bits when the MPC8240 accesses external memory.

For I/O transfers in little-endian mode to transfer bytes properly, they must be performed as if the bytes transferred were accessed one at a time using the little-endian address modification appropriate for the single-byte transfers (that is, the lowest order address bits must be XORed with 0b111). This does not mean that I/O operations in little-endian systems must be performed using only one-byte-wide transfers. Data transfers can be as wide as desired, but the order of the bytes within double words must be as if they were fetched or stored one at a time. That is, for a true little-endian I/O device, the system must provide a way to munge and unmunge the addresses and reverse the bytes within a double word (MSB to LSB).

A load or store that maps to a control register on an external device may require the bytes of the register data to be reversed. If this reversal is required, the load and store with byte-reverse instructions (**lhbrx**, **lwbrx**, **sthbrx**, and **stwbrx**) may be used.

B.5 Setting the Endian Mode of Operation

The MPC8240 powers up in big-endian mode. The endian mode should be set early in the initialization routine and remain unchanged for the duration of system operation. To switch between the different endian modes of operation, the processor core must run in serialized mode and the caches must be disabled. Switching back and forth between endian modes is not recommended.

To switch the system from big-endian to little-endian mode, the LE and ILE bits in the processor core's MSR should be set using an **mtmsr** instruction that resides on an odd word boundary (A[29] = 1). The instruction that is executed next is fetched from this address plus 8. (If the **mtmsr** instruction resides on an even word boundary (A[29] = 0), then the instruction would be executed twice due to the address munging of little-endian mode.) After the processor core has been programmed for little-endian mode, the PICR1[LE_MODE] parameter in the peripheral control logic is set.

To switch the system from little- to big-endian mode, the LE and ILE bits in the processor core's MSR are cleared using an **mtmsr** instruction that resides on an even word boundary (A[29] = 0). The instruction that is executed next is fetched from this address plus 12. After the processor core is programmed for big-endian mode, the PICR1[LE_MODE] parameter in the peripheral control logic is cleared.

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Appendix C
Initialization Example

This appendix contains an example PowerPC assembly language routine for initializing the configuration registers for the MPC8240 using address map B. It is excerpted from DINK32 source code available for download at http://www.motorola.com/semiconductors. DINK32 source code also contains examples on how to initialize the embedded utilities (EPIC, DMA, MU and I^2C). `/* entry: r3 contains MPC8240 Vendor ID */`

```
MPC8240Init:

        // save MPC8240 Vendor ID
        or    r11, r3, r3

          // If the MPC8240 is detected, it must be running on a
          // Sandpoint with the Unity (PPMC8240) board (or possibly
          // a Yellowknife X4 with an adapter card).
          // The board_type of Sandpoint+PMC8240 X4 is 4.  This code
          // stores the value 4 to sprg0, which will be stored to the
          // board_type variable after DINK is copied form ROM to RAM.

          addi     r3, r0, 0x4
          mtspr    sprg0, r3

// Errata to address latency timer RP 7/20/99
          addis    r3,r0,BMC_BASE     // Set LATENCY_TIMER
          ori          r3,r3,0x000d
          li      r4, 0x20      // Set to 0x20

        stwbrxr3,0,r5
    sync
    stb  r4, 1(r6)
    sync

          addis    r3,r0,BMC_BASE     // Set CACHE_LINE_SIZE
          ori          r3,r3,0x000c
          li      r4, 0x08      // Set to 0x08

          stwbrx   r3,0,r5
    sync
    stb  r4, 0(r6)
    sync

          addis    r3,r0,BMC_BASE     // Set PCI_CMD
          ori          r3,r3,0x0004
          li      r4, 0x0006      // Set to 06 (Memory Space)

          stwbrx   r3,0,r5
```


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```
    sync
    sthbrx  r4, 0, r6
    sync

         addis    r3,r0,BMC_BASE     // Set PCI_STAT
         ori      r3,r3,0x0006
         stwbrx   r3,0,r5
    sync

         li      r3, 0x0002
         lhbrx   r4, r3, r6         // Get old PCI_STAT
         sync
         ori     r4, r4, 0xffff     // Writing all ones will clear all bits in
         sthbrx  r4, r3, r6         // write the modified data to CONFIG_DATA

//-------PICR1

         addis    r3,r0,BMC_BASE     // Set PICR1 (A8)
         ori      r3,r3,PROCINTCONF1
         stwbrx   r3,0,r5
         sync

         lwbrx    r4,0,r6                    // Get PICR1 bits

         lis      r0,0x0011
         ori      r0,r0,0x0000
         and      r4,r4,r0           // preserve POR bits.

         lis      r0,0xff00
         oris    r0, r0, 0x0000      // burst read wt states = 0
         oris    r0, r0, 0x0004      // processor type = 603

         ori     r0, r0, 0x1000      //enable writes to flash
         ori     r0, r0, 0x0800      //enable mcp assertion
         ori     r0, r0, 0x0200      //enable data bus parking
         ori     r0, r0, 0x0008      //enable address bus parking
         or      r4, r4, r0          // sets the desired bits

         stwbrx r4,0,r6

//-------PICR2

         addis  r3,r0,BMC_BASE// Set PICR2 (AC)
         ori    r3,r3,PROCINTCONF2
         stwbrx r3,0,r5
         sync

         lwbrx    r4,0,r6                    // Get PICR2 bits

         lis      r0, 0xfff3          // clear snoop wt state bits
         ori      r0, r0, 0xfff3      // clear addr. phase wt state bits
         and      r4, r4, r0          // clears the undesired bits

         lis     r0, 0x0000          // set no-serial-config bit
         oris    r0, r0, 0x0400      // Recover RCS1 from PCI
//       oris    r0, r0, 0x0004      // snoop wt states = 1
         oris    r0, r0, 0x0000      // snoop wt states = 0
//       ori     r0, r0, 0x0004      // addr. phase wt states = 1
         ori     r0, r0, 0x0000      // addr. phase wt states = 0
```

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```
          or      r4, r4, r0

          stwbrx  r4,0,r6


//------ Embedded Unitility Memory Block Base Address Register( eumbbar )

          addis  r3,r0,BMC_BASE           // EUMBBAR (78) = 0xFC00_0000
        ori    r3,r3,0x0078
        stwbrx r3,0,r5

        lis    r4,0xfc00// Don't forget to map this area
        stwbrx r4,0,r6      // into the BATs
        sync


//! ===MCCR1=== MEMORY CONTROL CONFIGURATION
//!

          addis  r3,r0,BMC_BASE           // MCCR1 (F0) = 0x8800_0000
        ori    r3,r3,0x00F0
        stwbrx r3,0,r5
        addis  r4,r0,0x8800
        ori    r4,r4,0x0000// Set all banks to 64Mbit, 4 bank parts
        stwbrx r4,0,r6
        sync

//! ===MCCR2=== MEMORY CONTROL CONFIGURATION
//!

          addis  r3,r0,BMC_BASE// Set MCCR2 (F4)
          ori    r3,r3,0x00F4
          stwbrx r3,0,r5
          sync

          lis    r4, 0x0000          // Self-Refresh value
//        ori    r4, r4, 0x06b8      // 33 MHZ - REFINT
          ori    r4, r4, 0x023C      // 100 MHZ - REFINT

          stwbrx r4,0,r6
        sync


//! ===MCCR3=== MEMORY CONTROL CONFIGURATION
//!

          addis  r3,r0,BMC_BASE// Set MCCR3 (F8)
          ori    r3,r3,0x00F8
          stwbrx r3,0,r5
          sync

          lis    r4, 0x7840          // RDLAT=4 (Mem CAS Latency+1), REFREC=1000,
          ori    r4, r4, 0x0000      // No EDO/FP parameters set (SDRAM)

          stwbrx r4,0,r6
        sync

//! ===MCCR4=== MEMORY CONTROL CONFIGURATION
//!
```

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```
          addis  r3,r0,BMC_BASE// Set MCCR4 (FC)
          ori    r3,r3,0x00Fc
          stwbrx r3,0,r5
          sync

          lis    r4, 0x3530          // 100MHz setting, registered buffers
                                                  // PRETOACT=3, ACTOPRE=5
          ori    r4, r4,0x3239      // CL=3, ACTORW=3, BSTOPRE(6-9)=9
//        ori    r4, r4,0x2239      // CL=2, ACTORW=3, BSTOPRE(6-9)=9

          stwbrx r4,0,r6
         sync


//-------MSAR1/etc.
// Set each bank to 32MB (0-1FFFFFF, 2000000-...)

          addis  r3,r0,BMC_BASE// Set MSAR1 (80)
          ori    r3,r3,MEMSTARTADDR1
          stwbrx r3,0,r5

          addis  r4,r0,0x6040
          ori    r4,r4,0x2000
          stwbrx r4,0,r6

          addis  r3,r0,BMC_BASE// Set MSAR2 (84)
          ori    r3,r3,MEMSTARTADDR2
          stwbrx r3,0,r5

          addis  r4,r0,0xe0c0
          ori    r4,r4,0xa080
          stwbrx r4,0,r6

          addis  r3,r0,BMC_BASE// Set MESAR1 (88)
          ori    r3,r3,XMEMSTARTADDR1
          stwbrx r3,0,r5

          addis  r4,r0,0x0000
          ori    r4,r4,0x0000
          stwbrx r4,0,r6

          addis  r3,r0,BMC_BASE// Set MESAR2 (8c)
          ori    r3,r3,XMEMSTARTADDR2
          stwbrx r3,0,r5

          addis  r4,r0,0x0000
          ori    r4,r4,0x0000
          stwbrx r4,0,r6

          addis  r3,r0,BMC_BASE// Set MEAR1 (90)
          ori    r3,r3,MEMENDADDR1
          stwbrx r3,0,r5

          addis  r4,r0,0x7f5f
          ori    r4,r4,0x3f1f// ending address of bank 0 is
                                                 // 0x0x01FFFFFF
          stwbrx r4,0,r6
```


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```
          addis  r3,r0,BMC_BASE// Set MEAR2 (94)
          ori    r3,r3,MEMENDADDR2
          stwbrx r3,0,r5

          addis  r4,r0,0xffdf
          ori    r4,r4,0xbf9f
          stwbrx r4,0,r6

          addis  r3,r0,BMC_BASE// MEEAR1 (98) =
          ori    r3,r3,XMEMENDADDR1
          stwbrx r3,0,r5

          addis  r4,r0,0x0000
          ori    r4,r4,0x0000
          stwbrx r4,0,r6

          addis  r3,r0,BMC_BASE// MEEAR2 (9c) =
          ori    r3,r3,XMEMENDADDR2
          stwbrx r3,0,r5

          addis  r4,r0,0x0000
          ori    r4,r4,0x0000
          stwbrx r4,0,r6


//-------ODCR

          addis  r3,r0,BMC_BASE// Set ODCR
          ori    r3,r3,0x73
          stwbrx r3,0,r5
          sync

          lbz    r4, 3(r6)           // read current register state

//        li     r4, 0x00cd          // 20 ohm memory bus
//        li     r4, 0x00dc          // 13 ohm memory bus
//        li     r4, 0x00dd          // 8 ohm memory bus
          li     r4, 0x00ff          // -default settings-

          stb    r4, 3(r6)           // New settings.

//-------MBEN

          addis  r3,r0,BMC_BASE// Set MBEN (a0)
          ori    r3,r3,0xa0
          stwbrx r3,0,r5
          li       r4,0x03                      // Enable bank 0 and 1 (for dual-
          stb     r4, 0(r6)  // bank SODIMMs.

//-------PGMAX

          addis  r3,r0,BMC_BASE
          ori    r3,r3,0xa3
          stwbrx r3,0,r5
          li     r4, 0x0032          // 33MHz value w/ROMFAL=8
          stb    r4, 3(r6)           // write the modified data to CONFIG_DATA

// Wait before initialize other registers
```


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```
          lis       r4,0x0001
          mtctr   r4

MPC8240X4wait200us:
          bdnz      MPC8240X4wait200us

// Set MEMGO bit

          addis  r3,r0,BMC_BASE// MCCR1 (F0) |= PGMAX
          ori    r3,r3,0x00F0
          stwbrx r3,0,r5
          sync

          lwbrx  r4,0,r6               // old MCCR1

          lis    r0, 0x0008          // MEMGO=1
          ori    r0, r0, 0x0000
          or     r4, r4, r0          // set the MEMGO bit
          stwbrx r4, 0, r6


// Wait again

          addis     r4,r0,0x0002
          ori       r4,r4,0xffff

          mtctr     r4
MPC8240X4wait8ref:
          bdnz      MPC8240X4wait8ref

//------ WP1_CNTL_TRIG

        addis  r3,r0,BMC_BASE_HIGH           // WP1_CNTL_TRIG (0xFF018) =
        ori    r3,r3,0xF018
        stwbrx r3,0,r5

        addis  r4,r0,0x0000
        ori    r4,r4,0x0180
        stwbrx r4,0,r6

//------ WP1_ADDR_TRIG

        addis  r3,r0,BMC_BASE_HIGH           // WP1_ADDR_TRIG (0xFF01C) =
        ori    r3,r3,0xF01C
        stwbrx r3,0,r5

        addis  r4,r0,0x0006     // Set to 0x60000
        ori    r4,r4,0x0000
        stwbrx r4,0,r6

//------ WP1_CNTL_MASK

        addis  r3,r0,BMC_BASE_HIGH           // WP1_CNTL_MASK (0xFF020) =
        ori    r3,r3,0xF020
        stwbrx r3,0,r5

        addis  r4,r0,0x0000
        ori    r4,r4,0x0180
        stwbrx r4,0,r6
```

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```
//------ WP1_ADDR_MASK

        addis  r3,r0,BMC_BASE_HIGH           // WP1_ADDR_MASK (0xFF024) =
        ori    r3,r3,0xF024
        stwbrx r3,0,r5

        addis  r4,r0,0xFFFF
        ori    r4,r4,0xFFFF
        stwbrx r4,0,r6

//------ WP_CONTROL

        addis  r3,r0,BMC_BASE_HIGH           // WP_CONTROL (0xFF048) =
        ori    r3,r3,0xF048
        stwbrx r3,0,r5

        addis  r4,r0,0x0000
        ori    r4,r4,0x01C6
        stwbrx r4,0,r6


        addis  r4,r0,0x0100     // Enable Watchpoint on seperate write
        ori    r4,r4,0x01C6
        stwbrx r4,0,r6

         sync
         eieio

        lis    r3, 0x0
         or     r3, r3, r11                   // restore MPC8240 Vendor ID

         blr

/*********************************************************
 * function: get_eumbbar
 *
 * output: r3 - content of eumbbar
 *********************************************************/
      .text
      .align 2
      .global get_eumbbar
get_eumbbar:

          lis      r4,config_addr@h
          ori      r4,r4,config_addr@l
          lwz      r4,0(r4)

          lis      r3,EUMBBAR_HI
          ori      r3,r3,EUMBBAR_LO
          stwbrx   r3,0,r4

          lis      r4,config_data@h
          ori      r4,r4,config_data@l
          lwz      r4,0(r4)

          lwbrx    r3,0,r4

          blr
```


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Appendix D
PowerPC Instruction Set Listings

This appendix lists the MPC8240 microprocessor's instruction set as well as the additional PowerPC instructions not implemented in the MPC8240. Instructions are sorted by mnemonic, opcode, function, and form. Also included in this appendix is a quick reference table that contains general information, such as the architecture level, privilege level, and form, and indicates if the instruction is 64-bit and optional.

Note that split fields, that represent the concatenation of sequences from left to right, are shown in lowercase. For more information refer to Chapter 8, "Instruction Set," in *The Programming Environments Manual.*

D.1 Instructions Sorted by Mnemonic

Table D-1 lists the instructions implemented in the PowerPC architecture in alphabetical order by mnemonic.

Table D-1. Complete Instruction List Sorted by Mnemonic

Key:

Reserved bits

Instruction not implemented in the MPC8240

Name	0	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
addx	31	D					A					B					OE	266								Rc
addcx	31	D					A					B					OE	10								Rc
addex	31	D					A					B					OE	138								Rc
addi	14	D					A					SIMM															
addic	12	D					A					SIMM															
addic.	13	D					A					SIMM															
addis	15	D					A					SIMM															
addmex	31	D					A					0 0 0 0 0					OE	234								Rc
addzex	31	D					A					0 0 0 0 0					OE	202								Rc
andx	31	S					A					B					28										Rc
andcx	31	S					A					B					60										Rc

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Name	0	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
andi.	28	S					A					UIMM															
andis.	29	S					A					UIMM															
bx	18	LI																								AA	LK
bcx	16	BO					BI					BD														AA	LK
bcctrx	19	BO					BI					0 0 0 0 0					528										LK
bclrx	19	BO					BI					0 0 0 0 0					16										LK
cmp	31	crfD			0	L	A					B					0										0
cmpi	11	crfD			0	L	A					SIMM															
cmpl	31	crfD			0	L	A					B					32										0
cmpli	10	crfD			0	L	A					UIMM															
cntlzdx [4]	31	S					A					0 0 0 0 0					58										Rc
cntlzwx	31	S					A					0 0 0 0 0					26										Rc
crand	19	crbD					crbA					crbB					257										0
crandc	19	crbD					crbA					crbB					129										0
creqv	19	crbD					crbA					crbB					289										0
crnand	19	crbD					crbA					crbB					225										0
crnor	19	crbD					crbA					crbB					33										0
cror	19	crbD					crbA					crbB					449										0
crorc	19	crbD					crbA					crbB					417										0
crxor	19	crbD					crbA					crbB					193										0
dcbf	31	0 0 0 0 0					A					B					86										0
dcbi [1]	31	0 0 0 0 0					A					B					470										0
dcbst	31	0 0 0 0 0					A					B					54										0
dcbt	31	0 0 0 0 0					A					B					278										0
dcbtst	31	0 0 0 0 0					A					B					246										0
dcbz	31	0 0 0 0 0					A					B					1014										0
divdx [4]	31	D					A					B				OE	489										Rc
divdux [4]	31	D					A					B				OE	457										Rc
divwx	31	D					A					B				OE	491										Rc
divwux	31	D					A					B				OE	459										Rc
eciwx	31	D					A					B					310										0
ecowx	31	S					A					B					438										0
eieio	31	0 0 0 0 0					0 0 0 0 0					0 0 0 0 0					854										0

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Name	0	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
eqvx	31	S					A					B					284										Rc
extsbx	31	S					A					0 0 0 0 0					954										Rc
extshx	31	S					A					0 0 0 0 0					922										Rc
extswx [4]	31	S					A					0 0 0 0 0					986										Rc
fabsx [7]	63	D					0 0 0 0 0					B					264										Rc
faddx	63	D					A					B					0 0 0 0 0					21					Rc
faddsx [7]	59	D					A					B					0 0 0 0 0					21					Rc
fcfidx [4,7]	63	D					0 0 0 0 0					B					846										Rc
fcmpo [7]	63	crfD			0 0		A					B					32										0
fcmpu [7]	63	crfD			0 0		A					B					0										0
fctidx [4,7]	63	D					0 0 0 0 0					B					814										Rc
fctidzx [4,7]	63	D					0 0 0 0 0					B					815										Rc
fctiwx [7]	63	D					0 0 0 0 0					B					14										Rc
fctiwzx [7]	63	D					0 0 0 0 0					B					15										Rc
fdivx [7]	63	D					A					B					0 0 0 0 0					18					Rc
fdivsx [7]	59	D					A					B					0 0 0 0 0					18					Rc
fmaddx [7]	63	D					A					B					C					29					Rc
fmaddsx [7]	59	D					A					B					C					29					Rc
fmrx [7]	63	D					0 0 0 0 0					B					72										Rc
fmsubx [7]	63	D					A					B					C					28					Rc
fmsubsx [7]	59	D					A					B					C					28					Rc
fmulx [7]	63	D					A					0 0 0 0 0					C					25					Rc
fmulsx [7]	59	D					A					0 0 0 0 0					C					25					Rc
fnabsx [7]	63	D					0 0 0 0 0					B					136										Rc
fnegx [7]	63	D					0 0 0 0 0					B					40										Rc
fnmaddx [7]	63	D					A					B					C					31					Rc
fnmaddsx [7]	59	D					A					B					C					31					Rc
fnmsubx [7]	63	D					A					B					C					30					Rc
fnmsubsx [7]	59	D					A					B					C					30					Rc
fresx [5,7]	59	D					0 0 0 0 0					B					0 0 0 0 0					24					Rc
frspx [7]	63	D					0 0 0 0 0					B					12										Rc
frsqrtex [5,7]	63	D					0 0 0 0 0					B					0 0 0 0 0					26					Rc
fselx [5,7]	63	D					A					B					C					23					Rc

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Name	0	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
fsqrtx [5,7]	63	D					0	0	0	0	0	B					0	0	0	0	0	22					Rc
fsqrtsx [5,7]	59	D					0	0	0	0	0	B					0	0	0	0	0	22					Rc
fsubx [7]	63	D					A					B					0	0	0	0	0	20					Rc
fsubsx [7]	59	D					A					B					0	0	0	0	0	20					Rc
icbi	31	0	0	0	0	0	A					B					982										0
isync	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150										0
lbz	34	D					A					d															
lbzu	35	D					A					d															
lbzux	31	D					A					B					119										0
lbzx	31	D					A					B					87										0
ld [4]	58	D					A					ds														0	
ldarx [4]	31	D					A					B					84										0
ldu [4]	58	D					A					ds														1	
ldux [4]	31	D					A					B					53										0
ldx [4]	31	D					A					B					21										0
lfd [7]	50	D					A					d															
lfdu [7]	51	D					A					d															
lfdux [7]	31	D					A					B					631										0
lfdx [7]	31	D					A					B					599										0
lfs [7]	48	D					A					d															
lfsu [7]	49	D					A					d															
lfsux [7]	31	D					A					B					567										0
lfsx [7]	31	D					A					B					535										0
lha	42	D					A					d															
lhau	43	D					A					d															
lhaux	31	D					A					B					375										0
lhax	31	D					A					B					343										0
lhbrx	31	D					A					B					790										0
lhz	40	D					A					d															
lhzu	41	D					A					d															
lhzux	31	D					A					B					311										0
lhzx	31	D					A					B					279										0
lmw [3]	46	D					A					d															

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Name	0	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
lswi [3]	31	D					A					NB					597										0
lswx [3]	31	D					A					B					533										0
lwa [4]	58	D					A					ds														2	
lwarx	31	D					A					B					20										0
lwaux [4]	31	D					A					B					373										0
lwax [4]	31	D					A					B					341										0
lwbrx	31	D					A					B					534										0
lwz	32	D					A					d															
lwzu	33	D					A					d															
lwzux	31	D					A					B					55										0
lwzx	31	D					A					B					23										0
mcrf	19	crfD			0	0	crfS				0	0	0	0	0	0	0										0
mcrfs [7]	63	crfD			0	0	crfS				0	0	0	0	0	0	64										0
mcrxr	31	crfD			0	0	0	0	0	0	0	0	0	0	0	0	512										0
mfcr	31	D					0	0	0	0	0	0	0	0	0	0	19										0
mffsx [7]	63	D					0	0	0	0	0	0	0	0	0	0	583										Rc
mfmsr [1]	31	D					0	0	0	0	0	0	0	0	0	0	83										0
mfspr [2]	31	D					spr										339										0
mfsr [1]	31	D					0	SR				0	0	0	0	0	595										0
mfsrin [1]	31	D					0	0	0	0	0	B					659										0
mftb	31	D					tbr										371										0
mtcrf	31	S					0	CRM								0	144										0
mtfsb0x [7]	63	crbD					0	0	0	0	0	0	0	0	0	0	70										Rc
mtfsb1x [7]	63	crbD					0	0	0	0	0	0	0	0	0	0	38										Rc
mtfsfx [7]	63	0	FM								0	B					711										Rc
mtfsfix [7]	63	crfD			0	0	0	0	0	0	0	IMM				0	134										Rc
mtmsr [1]	31	S					0	0	0	0	0	0	0	0	0	0	146										0
mtspr [2]	31	S					spr										467										0
mtsr [1]	31	S					0	SR				0	0	0	0	0	210										0
mtsrin [1]	31	S					0	0	0	0	0	B					242										0
mulhdx [4]	31	D					A					B					0	73									Rc
mulhdux [4]	31	D					A					B					0	9									Rc
mulhwx	31	D					A					B					0	75									Rc

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Name	0	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
mulhwux	31	D					A					B					0	11									Rc
mulldx [4]	31	D					A					B					OE	233									Rc
mulli	7	D					A					SIMM															
mullwx	31	D					A					B					OE	235									Rc
nandx	31	S					A					B					476										Rc
negx	31	D					A					0 0 0 0 0					OE	104									Rc
norx	31	S					A					B					124										Rc
orx	31	S					A					B					444										Rc
orcx	31	S					A					B					412										Rc
ori	24	S					A					UIMM															
oris	25	S					A					UIMM															
rfi [1]	19	0 0 0 0 0					0 0 0 0 0					0 0 0 0 0					50										0
rldclx [4]	30	S					A					B					mb						8				Rc
rldcrx [4]	30	S					A					B					me						9				Rc
rldicx [4]	30	S					A					sh					mb						2		sh		Rc
rldiclx [4]	30	S					A					sh					mb						0		sh		Rc
rldicrx [4]	30	S					A					sh					me						1		sh		Rc
rldimix [4]	30	S					A					sh					mb						3		sh		Rc
rlwimix	20	S					A					SH					MB					ME					Rc
rlwinmx	21	S					A					SH					MB					ME					Rc
rlwnmx	23	S					A					B					MB					ME					Rc
sc	17	0 0 0 0 0					0 0 0 0 0					0 0 0 0 0 0 0 0 0 0 0 0 0 0													1		0
slbia [1,4,5]	31	0 0 0 0 0					0 0 0 0 0					0 0 0 0 0					498										0
slbie [1,4,5]	31	0 0 0 0 0					0 0 0 0 0					B					434										0
sldx [4]	31	S					A					B					27										Rc
slwx	31	S					A					B					24										Rc
sradx [4]	31	S					A					B					794										Rc
sradix [4]	31	S					A					sh					413									sh	Rc
srawx	31	S					A					B					792										Rc
srawix	31	S					A					SH					824										Rc
srdx [4]	31	S					A					B					539										Rc
srwx	31	S					A					B					536										Rc
stb	38	S					A					d															

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Name	0	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
stbu	39	S					A					d															
stbux	31	S					A					B					247										0
stbx	31	S					A					B					215										0
std [4]	62	S					A					ds														0	
stdcx. [4]	31	S					A					B					214										1
stdu [4]	62	S					A					ds														1	
stdux [4]	31	S					A					B					181										0
stdx [4]	31	S					A					B					149										0
stfd	54	S					A					d															
stfdu	55	S					A					d															
stfdux	31	S					A					B					759										0
stfdx	31	S					A					B					727										0
stfiwx [5]	31	S					A					B					983										0
stfs	52	S					A					d															
stfsu	53	S					A					d															
stfsux	31	S					A					B					695										0
stfsx	31	S					A					B					663										0
sth	44	S					A					d															
sthbrx	31	S					A					B					918										0
sthu	45	S					A					d															
sthux	31	S					A					B					439										0
sthx	31	S					A					B					407										0
stmw [3]	47	S					A					d															
stswi [3]	31	S					A					NB					725										0
stswx [3]	31	S					A					B					661										0
stw	36	S					A					d															
stwbrx	31	S					A					B					662										0
stwcx.	31	S					A					B					150										1
stwu	37	S					A					d															
stwux	31	S					A					B					183										0
stwx	31	S					A					B					151										0
subfx	31	D					A					B				OE	40										Rc
subfcx	31	D					A					B				OE	8										Rc

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Name	0	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
subfex	31	D					A					B					OE	136								Rc
subfic	08	D					A					SIMM															
subfmex	31	D					A					0	0	0	0	0	OE	232								Rc
subfzex	31	D					A					0	0	0	0	0	OE	200								Rc
sync	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	598									0
td [4]	31	TO					A					B					68									0
tdi [4]	02	TO					A					SIMM															
tlbia [1,5]	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	370									0
tlbie [1,5]	31	0	0	0	0	0	0	0	0	0	0	B					306									0
tlbld [1,6]	31	0	0	0	0	0	0	0	0	0	0	B					978									0
tlbli [1,6]	31	0	0	0	0	0	0	0	0	0	0	B					1010									0
tlbsync[1,5]	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	566									0
tw	31	TO					A					B					4									0
twi	03	TO					A					SIMM															
xorx	31	S					A					B					316									Rc
xori	26	S					A					UIMM															
xoris	27	S					A					UIMM															

[1] Supervisor-level instruction
[2] Supervisor- and user-level instruction
[3] Load and store string or multiple instruction
[4] 64-bit instruction
[5] Optional in the PowerPC architecture
[6] Implementation-specific instruction

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D.2 Instructions Sorted by Opcode

Table D-2 lists the instructions defined in the PowerPC architecture in numeric order by opcode.

Key:

Reserved bits

Instruction not implemented in the MPC8240

Table D-2. Complete Instruction List Sorted by Opcode

Name	0 5	6 7 8	9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25 26 27 28 29	30	31
tdi [4]	000010	TO		A	SIMM			
twi	000011	TO		A	SIMM			
mulli	000111	D		A	SIMM			
subfic	001000	D		A	SIMM			
cmpli	001010	crfD	0 L	A	UIMM			
cmpi	001011	crfD	0 L	A	SIMM			
addic	001100	D		A	SIMM			
addic.	001101	D		A	SIMM			
addi	001110	D		A	SIMM			
addis	001111	D		A	SIMM			
bcx	010000	BO		BI	BD		AA	LK
sc	010001	00000		00000	00000000000000		1	0
bx	010010	LI					AA	LK
mcrf	010011	crfD	00	crfS 00	00000	0000000000		0
bclrx	010011	BO		BI	00000	0000010000		LK
crnor	010011	crbD		crbA	crbB	0000100001		0
rfi	010011	00000		00000	00000	0000110010		0
crandc	010011	crbD		crbA	crbB	0010000001		0
isync	010011	00000		00000	00000	0010010110		0
crxor	010011	crbD		crbA	crbB	0011000001		0
crnand	010011	crbD		crbA	crbB	0011100001		0
crand	010011	crbD		crbA	crbB	0100000001		0
creqv	010011	crbD		crbA	crbB	0100100001		0
crorc	010011	crbD		crbA	crbB	0110100001		0
cror	010011	crbD		crbA	crbB	0111000001		0
bcctrx	010011	BO		BI	00000	1000010000		LK

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Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
rlwimix	0 1 0 1 0 0		S					A					SH					MB					ME					Rc
rlwinmx	0 1 0 1 0 1		S					A					SH					MB					ME					Rc
rlwnmx	0 1 0 1 1 1		S					A					B					MB					ME					Rc
ori	0 1 1 0 0 0		S					A					UIMM															
oris	0 1 1 0 0 1		S					A					UIMM															
xori	0 1 1 0 1 0		S					A					UIMM															
xoris	0 1 1 0 1 1		S					A					UIMM															
andi.	0 1 1 1 0 0		S					A					UIMM															
andis.	0 1 1 1 0 1		S					A					UIMM															
rldiclx[4]	0 1 1 1 1 0		S					A					sh					mb					0 0 0			sh		Rc
rldicrx[4]	0 1 1 1 1 0		S					A					sh					me					0 0 1			sh		Rc
rldicx[4]	0 1 1 1 1 0		S					A					sh					mb					0 1 0			sh		Rc
rldimix[4]	0 1 1 1 1 0		S					A					sh					mb					0 1 1			sh		Rc
rldclx[4]	0 1 1 1 1 0		S					A					B					mb					0 1 0 0 0					Rc
rldcrx[4]	0 1 1 1 1 0		S					A					B					me					0 1 0 0 1					Rc
cmp	0 1 1 1 1 1		crfD			0	L	A					B					0 0 0 0 0 0 0 0 0 0										0
tw	0 1 1 1 1 1		TO					A					B					0 0 0 0 0 0 0 1 0 0										0
subfcx	0 1 1 1 1 1		D					A					B					OE	0 0 0 0 0 0 1 0 0 0									Rc
mulhdux[4]	0 1 1 1 1 1		D					A					B					0	0 0 0 0 0 0 1 0 0 1									Rc
addcx	0 1 1 1 1 1		D					A					B					OE	0 0 0 0 0 0 1 0 1 0									Rc
mulhwux	0 1 1 1 1 1		D					A					B					0	0 0 0 0 0 0 1 0 1 1									Rc
mfcr	0 1 1 1 1 1		D					0 0 0 0 0					0 0 0 0 0					0 0 0 0 0 1 0 0 1 1										0
lwarx	0 1 1 1 1 1		D					A					B					0 0 0 0 0 1 0 1 0 0										0
ldx [4]	0 1 1 1 1 1		D					A					B					0 0 0 0 0 1 0 1 0 1										0
lwzx	0 1 1 1 1 1		D					A					B					0 0 0 0 0 1 0 1 1 1										0
slwx	0 1 1 1 1 1		S					A					B					0 0 0 0 0 1 1 0 0 0										Rc
cntlzwx	0 1 1 1 1 1		S					A					0 0 0 0 0					0 0 0 0 0 1 1 0 1 0										Rc
sldx[4]	0 1 1 1 1 1		S					A					B					0 0 0 0 0 1 1 0 1 1										Rc
andx	0 1 1 1 1 1		S					A					B					0 0 0 0 0 1 1 1 0 0										Rc
cmpl	0 1 1 1 1 1		crfD			0	L	A					B					0 0 0 0 1 0 0 0 0 0										0
subfx	0 1 1 1 1 1		D					A					B					OE	0 0 0 0 1 0 1 0 0 0									Rc
ldux [4]	0 1 1 1 1 1		D					A					B					0 0 0 0 1 1 0 1 0 1										0

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Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
dcbst	0 1 1 1 1 1		0	0	0	0	0	A					B					0	0	0	0	1	1	0	1	1	0	0
lwzux	0 1 1 1 1 1		D					A					B					0	0	0	0	1	1	0	1	1	1	0
cntlzdx [4]	0 1 1 1 1 1		S					A					0	0	0	0	0	0	0	0	1	1	1	0	1	0	Rc
andcx	0 1 1 1 1 1		S					A					B					0	0	0	0	1	1	1	1	0	0	Rc
td [4]	0 1 1 1 1 1		TO					A					B					0	0	0	1	0	0	0	1	0	0	0
mulhdx [4]	0 1 1 1 1 1		D					A					B					0	0	0	0	1	0	0	1	0	0	1	Rc
mulhwx	0 1 1 1 1 1		D					A					B					0	0	0	0	1	0	0	1	0	1	1	Rc
mfmsr	0 1 1 1 1 1		D					0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	0
ldarx [4]	0 1 1 1 1 1		D					A					B					0	0	0	1	0	1	0	1	0	0	0
dcbf	0 1 1 1 1 1		0	0	0	0	0	A					B					0	0	0	1	0	1	0	1	1	0	0
lbzx	0 1 1 1 1 1		D					A					B					0	0	0	1	0	1	0	1	1	1	0
negx	0 1 1 1 1 1		D					A					0	0	0	0	0	OE	0	0	1	1	0	1	0	0	0	Rc
lbzux	0 1 1 1 1 1		D					A					B					0	0	0	1	1	1	0	1	1	1	0
norx	0 1 1 1 1 1		S					A					B					0	0	0	1	1	1	1	1	0	0	Rc
subfex	0 1 1 1 1 1		D					A					B					OE	0	0	1	0	0	0	1	0	0	Rc
addex	0 1 1 1 1 1		D					A					B					OE	0	0	1	0	0	0	1	0	1	Rc
mtcrf	0 1 1 1 1 1		S					0	CRM								0	0	0	1	0	0	1	0	0	0	0	0
mtmsr	0 1 1 1 1 1		S					0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	1	0	0
stdx [4]	0 1 1 1 1 1		S					A					B					0	0	1	0	0	1	0	1	0	0	0
stwcx.	0 1 1 1 1 1		S					A					B					0	0	1	0	0	1	0	1	1	0	1
stwx	0 1 1 1 1 1		S					A					B					0	0	1	0	0	1	0	1	1	1	0
stdux [4]	0 1 1 1 1 1		S					A					B					0	0	1	0	1	1	0	1	0	1	0
stwux	0 1 1 1 1 1		S					A					B					0	0	1	0	1	1	0	1	1	1	0
subfzex	0 1 1 1 1 1		D					A					0	0	0	0	0	OE	0	1	1	0	0	1	0	0	0	Rc
addzex	0 1 1 1 1 1		D					A					0	0	0	0	0	OE	0	1	1	0	0	1	0	1	0	Rc
mtsr	0 1 1 1 1 1		S					0	SR				0	0	0	0	0	0	0	1	1	0	1	0	0	1	0	0
stdcx. [4]	0 1 1 1 1 1		S					A					B					0	0	1	0	1	1	0	1	0	1	1
stbx	0 1 1 1 1 1		S					A					B					0	0	1	0	1	1	1	0	1	1	1	0
subfmex	0 1 1 1 1 1		D					A					0	0	0	0	0	OE	0	1	1	1	0	1	0	0	0	Rc
mulld [4]	0 1 1 1 1 1		D					A					B					OE	0	1	1	1	0	1	0	0	1	Rc
addmex	0 1 1 1 1 1		D					A					0	0	0	0	0	OE	0	1	1	1	0	1	0	1	0	Rc
mullwx	0 1 1 1 1 1		D					A					B					OE	0	1	1	1	0	1	0	1	1	Rc
mtsrin	0 1 1 1 1 1		S					0	0	0	0	0	B					0	0	1	1	1	0	0	1	0	0	0

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Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
dcbtst	0 1 1 1 1 1		0	0	0	0	0	A					B					0	0	1	1	1	0	1	1	0		0
stbux	0 1 1 1 1 1		S					A					B					0	0	1	1	1	0	1	1	1		0
addx	0 1 1 1 1 1		D					A					B					OE	0	1	0	0	0	0	1	0		Rc
dcbt	0 1 1 1 1 1		0	0	0	0	0	A					B					0	1	0	0	0	1	0	1	1	0	0
lhzx	0 1 1 1 1 1		D					A					B					0	1	0	0	0	1	0	1	1	1	0
eqvx	0 1 1 1 1 1		S					A					B					0	1	0	0	0	1	1	1	0	0	Rc
tlbie [1,5]	0 1 1 1 1 1		0	0	0	0	0	0	0	0	0	0	B					0	1	0	0	1	1	0	0	1	0	0
eciwx	0 1 1 1 1 1		D					A					B					0	1	0	0	1	1	0	1	1	0	0
lhzux	0 1 1 1 1 1		D					A					B					0	1	0	0	1	1	0	1	1	1	0
xorx	0 1 1 1 1 1		S					A					B					0	1	0	0	1	1	1	1	0	0	Rc
mfspr [2]	0 1 1 1 1 1		D					spr										0	1	0	1	0	1	0	0	1	1	0
lwax [4]	0 1 1 1 1 1		D					A					B					0	1	0	1	0	1	0	1	0	1	0
lhax	0 1 1 1 1 1		D					A					B					0	1	0	1	0	1	0	1	1	1	0
tlbia [1,5]	0 1 1 1 1 1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	0	1	0	0
mftb	0 1 1 1 1 1		D					tbr										0	1	0	1	1	1	0	0	1	1	0
lwaux [4]	0 1 1 1 1 1		D					A					B					0	1	0	1	1	1	0	1	0	1	0
lhaux	0 1 1 1 1 1		D					A					B					0	1	0	1	1	1	0	1	1	1	0
sthx	0 1 1 1 1 1		S					A					B					0	1	1	0	0	1	0	1	1	1	0
orcx	0 1 1 1 1 1		S					A					B					0	1	1	0	0	1	1	1	0	0	Rc
sradix [4]	0 1 1 1 1 1		S					A					sh					1	1	0	0	1	1	1	0	1	sh	Rc
slbie [1,4,5]	0 1 1 1 1 1		0	0	0	0	0	0	0	0	0	0	B					0	1	1	0	0	1	0	0	1	0	0
ecowx	0 1 1 1 1 1		S					A					B					0	1	1	0	1	1	0	1	1	0	0
sthux	0 1 1 1 1 1		S					A					B					0	1	1	0	1	1	0	1	1	1	0
orx	0 1 1 1 1 1		S					A					B					0	1	1	0	1	1	1	1	0	0	Rc
divdux [4]	0 1 1 1 1 1		D					A					B					OE	0	1	1	1	0	0	1	0	0	1	Rc
divwux	0 1 1 1 1 1		D					A					B					OE	0	1	1	1	0	0	1	0	1	1	Rc
mtspr [2]	0 1 1 1 1 1		S					spr										0	1	1	1	0	1	0	0	1	1	0
dcbi	0 1 1 1 1 1		0	0	0	0	0	A					B					0	1	1	1	0	1	0	1	1	0	0
nandx	0 1 1 1 1 1		S					A					B					0	1	1	1	0	1	1	1	0	0	Rc
divdx [4]	0 1 1 1 1 1		D					A					B					OE	0	1	1	1	1	0	1	0	0	1	Rc
divwx	0 1 1 1 1 1		D					A					B					OE	0	1	1	1	1	0	1	0	1	1	Rc
slbia [1,4,5]	0 1 1 1 1 1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	0	1	0	0
mcrxr	0 1 1 1 1 1		crfD			0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

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Name	0	5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31
lswx [3]	011111		D	A	B	1000010101	0
lwbrx	011111		D	A	B	1000010110	0
lfsx [7]	011111		D	A	B	1000010111	0
srwx	011111		S	A	B	1000011000	Rc
srdx [4]	011111		S	A	B	1000011011	Rc
tlbsync [1,5]	011111		00000	00000	00000	1000110110	0
lfsux [7]	011111		D	A	B	1000110111	0
mfsr	011111		D	0 SR	00000	1001010011	0
lswi [3]	011111		D	A	NB	1001010101	0
sync	011111		00000	00000	00000	1001010110	0
lfdx [7]	011111		D	A	B	1001010111	0
lfdux [7]	011111		D	A	B	1001110111	0
mfsrin [1]	011111		D	00000	B	1010010011	0
stswx [3]	011111		S	A	B	1010010101	0
stwbrx	011111		S	A	B	1010010110	0
stfsx	011111		S	A	B	1010010111	0
stfsux	011111		S	A	B	1010110111	0
stswi [3]	011111		S	A	NB	1011010101	0
stfdx [7]	011111		S	A	B	1011010111	0
stfdux [7]	011111		S	A	B	1011110111	0
lhbrx	011111		D	A	B	1100010110	0
srawx	011111		S	A	B	1100011000	Rc
sradx [4]	011111		S	A	B	1100011010	Rc
srawix	011111		S	A	SH	1100111000	Rc
eieio	011111		00000	00000	00000	1101010110	0
sthbrx	011111		S	A	B	1110010110	0
extshx	011111		S	A	00000	1110011010	Rc
extsbx	011111		S	A	00000	1110111010	Rc
tlbld [1,6]	011111		00000	00000	B	1111010010	0
icbi	011111		00000	A	B	1111010110	0
stfiwx [5]	011111		S	A	B	1111010111	0
extsw [4]	011111		S	A	00000	1111011010	Rc
dcbz	011111		00000	A	B	1111110110	0

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Name	0 5	6 7 8	9 10 11 12 13	14 15 16 17 18 19 20	21 22 23 24 25	26 27 28 29 30	31
lwz	100000	D	A	d			
lwzu	100001	D	A	d			
lbz	100010	D	A	d			
lbzu	100011	D	A	d			
stw	100100	S	A	d			
stwu	100101	S	A	d			
stb	100110	S	A	d			
stbu	100111	S	A	d			
lhz	101000	D	A	d			
lhzu	101001	D	A	d			
lha	101010	D	A	d			
lhau	101011	D	A	d			
sth	101100	S	A	d			
sthu	101101	S	A	d			
lmw [3]	101110	D	A	d			
stmw [3]	101111	S	A	d			
lfs [7]	110000	D	A	d			
lfsu [7]	110001	D	A	d			
lfd [7]	110010	D	A	d			
lfdu [7]	110011	D	A	d			
stfs [7]	110100	S	A	d			
stfsu [7]	110101	S	A	d			
stfd [7]	110110	S	A	d			
stfdu [7]	110111	S	A	d			
ld [4]	111010	D	A	ds			00
ldu [4]	111010	D	A	ds			01
lwa [4]	111010	D	A	ds			10
fdivsx	111011	D	A	B	00000	10010	Rc
fsubsx	111011	D	A	B	00000	10100	Rc
faddsx	111011	D	A	B	00000	10101	Rc
fsqrtsx [5,7]	111011	D	00000	B	00000	10110	Rc
fresx [5,7]	111011	D	00000	B	00000	11000	Rc
fmulsx	111011	D	A	00000	C	11001	Rc

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Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
fmsubsx[7]	1 1 1 0 1 1		D					A					B					C					1 1 1 0 0				Rc
fmaddsx[7]	1 1 1 0 1 1		D					A					B					C					1 1 1 0 1				Rc
fnmsubsx	1 1 1 0 1 1		D					A					B					C					1 1 1 1 0				Rc
fnmaddsx	1 1 1 0 1 1		D					A					B					C					1 1 1 1 1				Rc
std [4]	1 1 1 1 1 0		S					A					ds													0 0	
stdu [4]	1 1 1 1 1 0		S					A					ds													0 1	
fcmpu[7]	1 1 1 1 1 1		crfD			0 0		A					B					0 0 0 0 0 0 0 0 0 0									0
frspx	1 1 1 1 1 1		D					0 0 0 0 0					B					0 0 0 0 0 0 1 1 0 0									Rc
fctiwx	1 1 1 1 1 1		D					0 0 0 0 0					B					0 0 0 0 0 0 1 1 1 0									
fctiwzx	1 1 1 1 1 1		D					0 0 0 0 0					B					0 0 0 0 0 0 1 1 1 1									Rc
fdivx	1 1 1 1 1 1		D					A					B					0 0 0 0 0					1 0 0 1 0				Rc
fsubx	1 1 1 1 1 1		D					A					B					0 0 0 0 0					1 0 1 0 0				Rc
faddx	1 1 1 1 1 1		D					A					B					0 0 0 0 0					1 0 1 0 1				Rc
fsqrtx[5,7]	1 1 1 1 1 1		D					0 0 0 0 0					B					0 0 0 0 0					1 0 1 1 0				Rc
fselx [5,7]	1 1 1 1 1 1		D					A					B					C					1 0 1 1 1				Rc
fmulx	1 1 1 1 1 1		D					A					0 0 0 0 0					C					1 1 0 0 1				Rc
frsqrtex [5,7]	1 1 1 1 1 1		D					0 0 0 0 0					B					0 0 0 0 0					1 1 0 1 0				Rc
fmsubx	1 1 1 1 1 1		D					A					B					C					1 1 1 0 0				Rc
fmaddx	1 1 1 1 1 1		D					A					B					C					1 1 1 0 1				Rc
fnmsubx	1 1 1 1 1 1		D					A					B					C					1 1 1 1 0				Rc
fnmaddx [7]	1 1 1 1 1 1		D					A					B					C					1 1 1 1 1				Rc
fcmpo [7]	1 1 1 1 1 1		crfD			0 0		A					B					0 0 0 0 1 0 0 0 0 0									0
mtfsb1x	1 1 1 1 1 1		crbD					0 0 0 0 0					0 0 0 0 0					0 0 0 0 1 0 0 1 1 0									Rc
fnegx	1 1 1 1 1 1		D					0 0 0 0 0					B					0 0 0 0 1 0 1 0 0 0									Rc
mcrfs[7]	1 1 1 1 1 1		crfD			0 0		crfS			0 0		0 0 0 0 0					0 0 0 1 0 0 0 0 0 0									0
mtfsb0x	1 1 1 1 1 1		crbD					0 0 0 0 0					0 0 0 0 0					0 0 0 1 0 0 0 1 1 0									Rc
fmrx	1 1 1 1 1 1		D					0 0 0 0 0					B					0 0 0 1 0 0 1 0 0 0									Rc
mtfsfix	1 1 1 1 1 1		crfD			0 0		0 0 0 0 0					IMM				0	0 0 1 0 0 0 0 1 1 0									Rc
fnabsx	1 1 1 1 1 1		D					0 0 0 0 0					B					0 0 1 0 0 0 1 0 0 0									Rc
fabsx	1 1 1 1 1 1		D					0 0 0 0 0					B					0 1 0 0 0 0 1 0 0 0									Rc
mffsx	1 1 1 1 1 1		D					0 0 0 0 0					0 0 0 0 0					1 0 0 1 0 0 0 1 1 1									Rc
mtfsfx	1 1 1 1 1 1		0	FM								0	B					1 0 1 1 0 0 0 1 1 1									Rc
fctidx [4,7]	1 1 1 1 1 1		D					0 0 0 0 0					B					1 1 0 0 1 0 1 1 1 0									Rc

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Name	0 5	6 7 8	9 10 11 12 13 14 15	16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31
fctidzx [4,7]	111111	D	00000	B	1100101111	Rc
fcfidx [4,7]	111111	D	00000	B	1101001110	Rc

[1] Supervisor-level instruction
[2] Supervisor- and user-level instruction
[3] Load and store string or multiple instruction
[4] 64-bit instruction
[5] Optional in the PowerPC architecture
[6] MPC8240-implementation specific instruction

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D.3 Instructions Grouped by Functional Categories

Table D-3 through Table D-30 list the PowerPC instructions grouped by function.

Key:

Reserved bits

Instruction not implemented in the MPC8240

Table D-3. Integer Arithmetic Instructions

Name	0 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21	22 23 24 25 26 27 28 29 30	31
addx	31	D	A	B	OE	266	Rc
addcx	31	D	A	B	OE	10	Rc
addex	31	D	A	B	OE	138	Rc
addi	14	D	A	SIMM			
addic	12	D	A	SIMM			
addic.	13	D	A	SIMM			
addis	15	D	A	SIMM			
addmex	31	D	A	0 0 0 0 0	OE	234	Rc
addzex	31	D	A	0 0 0 0 0	OE	202	Rc
divdx [4]	31	D	A	B	OE	489	Rc
divdux [4]	31	D	A	B	OE	457	Rc
divwx	31	D	A	B	OE	491	Rc
divwux	31	D	A	B	OE	459	Rc
mulhdx [4]	31	D	A	B	0	73	Rc
mulhdux [4]	31	D	A	B	0	9	Rc
mulhwx	31	D	A	B	0	75	Rc
mulhwux	31	D	A	B	0	11	Rc
mulld [4]	31	D	A	B	OE	233	Rc
mulli	07	D	A	SIMM			
mullwx	31	D	A	B	OE	235	Rc
negx	31	D	A	0 0 0 0 0	OE	104	Rc
subfx	31	D	A	B	OE	40	Rc
subfcx	31	D	A	B	OE	8	Rc
subficx	08	D	A	SIMM			
subfex	31	D	A	B	OE	136	Rc
subfmex	31	D	A	0 0 0 0 0	OE	232	Rc
subfzex	31	D	A	0 0 0 0 0	OE	200	Rc

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Table D-4. Integer Compare Instructions

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
cmp	31		crfD			0	L	A					B					0 0 0 0 0 0 0 0 0 0										0
cmpi	11		crfD			0	L	A					SIMM															
cmpl	31		crfD			0	L	A					B					32										0
cmpli	10		crfD			0	L	A					UIMM															

Table D-5. Integer Logical Instructions

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
andx	31		S					A					B					28										Rc
andcx	31		S					A					B					60										Rc
andi.	28		S					A					UIMM															
andis.	29		S					A					UIMM															
cntlzdx [4]	31		S					A					0 0 0 0 0					58										Rc
cntlzwx	31		S					A					0 0 0 0 0					26										Rc
eqvx	31		S					A					B					284										Rc
extsbx	31		S					A					0 0 0 0 0					954										Rc
extshx	31		S					A					0 0 0 0 0					922										Rc
extswx [4]	31		S					A					0 0 0 0 0					986										Rc
nandx	31		S					A					B					476										Rc
norx	31		S					A					B					124										Rc
orx	31		S					A					B					444										Rc
orcx	31		S					A					B					412										Rc
ori	24		S					A					UIMM															
oris	25		S					A					UIMM															
xorx	31		S					A					B					316										Rc
xori	26		S					A					UIMM															
xoris	27		S					A					UIMM															

Table D-6. Integer Rotate Instructions

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
rldclx [4]	30		S					A					B					mb						8				Rc
rldcrx [4]	30		S					A					B					me						9				Rc
rldicx [4]	30		S					A					sh					mb						2		sh		Rc
rldiclx [4]	30		S					A					sh					mb						0		sh		Rc

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Table D-6. Integer Rotate Instructions (Continued)

rldicrx [4]	30	S	A	sh	me	1	sh	Rc
rldimix [4]	30	S	A	sh	mb	3	sh	Rc
rlwimix	22	S	A	SH	MB	ME		Rc
rlwinmx	20	S	A	SH	MB	ME		Rc
rlwnmx	21	S	A	SH	MB	ME		Rc

Table D-7. Integer Shift Instructions

Name	0 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31
sldx [4]	31	S	A	B	27	Rc
slwx	31	S	A	B	24	Rc
sradx [4]	31	S	A	B	794	Rc
sradix [4]	31	S	A	sh	413 sh	Rc
srawx	31	S	A	B	792	Rc
srawix	31	S	A	SH	824	Rc
srdx [4]	31	S	A	B	539	Rc
srwx	31	S	A	B	536	Rc

Table D-8. Floating-Point Arithmetic Instructions[7]

Name	0 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25	26 27 28 29 30	31
faddx	63	D	A	B	0 0 0 0 0	21	Rc
faddsx	59	D	A	B	0 0 0 0 0	21	Rc
fdivx	63	D	A	B	0 0 0 0 0	18	Rc
fdivsx	59	D	A	B	0 0 0 0 0	18	Rc
fmulx	63	D	A	0 0 0 0 0	C	25	Rc
fmul*s*x	59	D	A	0 0 0 0 0	C	25	Rc
fresx [5]	59	D	0 0 0 0 0	B	0 0 0 0 0	24	Rc
frsqrtex [5]	63	D	0 0 0 0 0	B	0 0 0 0 0	26	Rc
fsubx	63	D	A	B	0 0 0 0 0	20	Rc
fsubsx	59	D	A	B	0 0 0 0 0	20	Rc
fselx [5]	63	D	A	B	C	23	Rc
fsqrtx [5]	63	D	0 0 0 0 0	B	0 0 0 0 0	22	Rc
fsqrtsx [5]	59	D	0 0 0 0 0	B	0 0 0 0 0	22	Rc

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Table D-9. Floating-Point Multiply-Add Instructions[7]

Name	0 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25	26 27 28 29 30	31
fmaddx	63	D	A	B	C	29	Rc
fmaddsx	59	D	A	B	C	29	Rc
fmsubx	63	D	A	B	C	28	Rc
fmsubsx	59	D	A	B	C	28	Rc
fnmaddx	63	D	A	B	C	31	Rc
fnmaddsx	59	D	A	B	C	31	Rc
fnmsubx	63	D	A	B	C	30	Rc
fnmsubsx	59	D	A	B	C	30	Rc

Table D-10. Floating-Point Rounding and Conversion Instructions[7]

Name	0 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25	26 27 28 29 30	31
fcfidx [4]	63	D	0 0 0 0 0	B	846		Rc
fctidx [4]	63	D	0 0 0 0 0	B	814		Rc
fctidzx [4]	63	D	0 0 0 0 0	B	815		Rc
fctiwx	63	D	0 0 0 0 0	B	14		Rc
fctiwzx	63	D	0 0 0 0 0	B	15		Rc
frspx	63	D	0 0 0 0 0	B	12		Rc

Table D-11. Floating-Point Compare Instructions[7]

Name	0 5	6 7 8	9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25	26 27 28 29 30	31
fcmpo	63	crfD	0 0	A	B	32		0
fcmpu	63	crfD	0 0	A	B	0		0

Table D-12. Floating-Point Status and Control Register Instructions[7]

Name	0 5	6 7 8	9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25	26 27 28 29 30	31
mcrfs	63	crfD	0 0	crfS 0 0	0 0 0 0 0	64		0
mffsx	63	D		0 0 0 0 0	0 0 0 0 0	583		Rc
mtfsb0x	63	crbD		0 0 0 0 0	0 0 0 0 0	70		Rc
mtfsb1x	63	crbD		0 0 0 0 0	0 0 0 0 0	38		Rc
mtfsfx	31	0	FM	0	B	711		Rc
mtfsfix	63	crfD	0 0	0 0 0 0 0	IMM 0	134		Rc

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Table D-13. Integer Load Instructions

Name	0 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31
lbz	34	D	A	d		
lbzu	35	D	A	d		
lbzux	31	D	A	B	119	0
lbzx	31	D	A	B	87	0
ld [4]	58	D	A	ds		0
ldu [4]	58	D	A	ds		1
ldux [4]	31	D	A	B	53	0
ldx [4]	31	D	A	B	21	0
lha	42	D	A	d		
lhau	43	D	A	d		
lhaux	31	D	A	B	375	0
lhax	31	D	A	B	343	0
lhz	40	D	A	d		
lhzu	41	D	A	d		
lhzux	31	D	A	B	311	0
lhzx	31	D	A	B	279	0
lwa [4]	58	D	A	ds		2
lwaux [4]	31	D	A	B	373	0
lwax [4]	31	D	A	B	341	0
lwz	32	D	A	d		
lwzu	33	D	A	d		
lwzux	31	D	A	B	55	0
lwzx	31	D	A	B	23	0

Table D-14. Integer Store Instructions

Name	0 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31
stb	38	S	A	d		
stbu	39	S	A	d		
stbux	31	S	A	B	247	0
stbx	31	S	A	B	215	0
std [4]	62	S	A	ds		0
stdu [4]	62	S	A	ds		1
stdux [4]	31	S	A	B	181	0

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Table D-14. Integer Store Instructions (Continued)

stdx [4]	31	S	A	B	149	0
sth	44	S	A	d		
sthu	45	S	A	d		
sthux	31	S	A	B	439	0
sthx	31	S	A	B	407	0
stw	36	S	A	d		
stwu	37	S	A	d		
stwux	31	S	A	B	183	0
stwx	31	S	A	B	151	0

Table D-15. Integer Load and Store with Byte-Reverse Instructions

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
lhbrx	31	D						A					B					790										0
lwbrx	31	D						A					B					534										0
sthbrx	31	S						A					B					918										0
stwbrx	31	S						A					B					662										0

Table D-16. Integer Load and Store Multiple Instructions

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
lmw [3]	46	D						A					d															
stmw [3]	47	S						A					d															

Table D-17. Integer Load and Store String Instructions

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
lswi [3]	31	D						A					NB					597										0
lswx [3]	31	D						A					B					533										0
stswi [3]	31	S						A					NB					725										0
stswx [3]	31	S						A					B					661										0

Table D-18. Memory Synchronization Instructions

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
eieio	31	0 0 0 0 0						0 0 0 0 0					0 0 0 0 0					854										0
isync	19	0 0 0 0 0						0 0 0 0 0					0 0 0 0 0					150										0
ldarx [4]	31	D						A					B					84										0
lwarx	31	D						A					B					20										0
stdcx. [4]	31	S						A					B					214										1

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Table D-18. Memory Synchronization Instructions (Continued)

stwcx.	31	S	A	B	150	1
sync	31	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	598	0

Table D-19. Floating-Point Load Instructions[7]

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
lfd	50		D					A					d															
lfdu	51		D					A					d															
lfdux	31		D					A					B					631										0
lfdx	31		D					A					B					599										0
lfs	48		D					A					d															
lfsu	49		D					A					d															
lfsux	31		D					A					B					567										0
lfsx	31		D					A					B					535										0

Table D-20. Floating-Point Store Instructions[7]

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
stfd	54		S					A					d															
stfdu	55		S					A					d															
stfdux	31		S					A					B					759										0
stfdx	31		S					A					B					727										0
stfiwx [5]	31		S					A					B					983										0
stfs	52		S					A					d															
stfsu	53		S					A					d															
stfsux	31		S					A					B					695										0
stfsx	31		S					A					B					663										0

Table D-21. Floating-Point Move Instructions[7]

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
fabsx	63		D					0	0	0	0	0	B					264										Rc
fmrx	63		D					0	0	0	0	0	B					72										Rc
fnabsx	63		D					0	0	0	0	0	B					136										Rc
fnegx	63		D					0	0	0	0	0	B					40										Rc

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Table D-22. Branch Instructions

Name	0	5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31
bx	18	LI				AA	LK
bcx	16	BO	BI	BD		AA	LK
bcctrx	19	BO	BI	0 0 0 0 0	528		LK
bclrx	19	BO	BI	0 0 0 0 0	16		LK

Table D-23. Condition Register Logical Instructions

Name	0	5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31
crand	19	crbD		crbA	crbB	257	0
crandc	19	crbD		crbA	crbB	129	0
creqv	19	crbD		crbA	crbB	289	0
crnand	19	crbD		crbA	crbB	225	0
crnor	19	crbD		crbA	crbB	33	0
cror	19	crbD		crbA	crbB	449	0
crorc	19	crbD		crbA	crbB	417	0
crxor	19	crbD		crbA	crbB	193	0
mcrf	19	crfD	0 0	crfS 0 0	0 0 0 0 0	0 0 0 0 0 0 0 0 0 0	0

Table D-24. System Linkage Instructions

Name	0	5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31
rfi [1]	19	0 0 0 0 0		0 0 0 0 0	0 0 0 0 0	50	0
sc	17	0 0 0 0 0		0 0 0 0 0	0 0 0 0 0 0 0 0 0 0 0 0 0 0	1	0

Table D-25. Trap Instructions

Name	0	5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31
td [4]	31	TO		A	B	68	0
tdi [4]	03	TO		A	SIMM		
tw	31	TO		A	B	4	0
twi	03	TO		A	SIMM		

Table D-26. Processor Control Instructions

Name	0	5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31
mcrxr	31	crfS	0 0	0 0 0 0 0	0 0 0 0 0	512	0
mfcr	31	D		0 0 0 0 0	0 0 0 0 0	19	0
mfmsr [1]	31	D		0 0 0 0 0	0 0 0 0 0	83	0
mfspr [2]	31	D		spr		339	0

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Table D-26. Processor Control Instructions (Continued)

	0		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
mftb	31			D					tpr										371											0
mtcrf	31			S					0			CRM						0	144											0
mtmsr [1]	31			S					0 0 0 0 0					0 0 0 0 0					146										0
mtspr [2]	31			D					spr										467											0

Table D-27. Cache Management Instructions

Name	0		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
dcbf	31			0 0 0 0 0					A					B					86										0
dcbi [1]	31			0 0 0 0 0					A					B					470										0
dcbst	31			0 0 0 0 0					A					B					54										0
dcbt	31			0 0 0 0 0					A					B					278										0
dcbtst	31			0 0 0 0 0					A					B					246										0
dcbz	31			0 0 0 0 0					A					B					1014										0
icbi	31			0 0 0 0 0					A					B					982										0

Table D-28. Segment Register Manipulation Instructions

Name	0		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
mfsr [1]	31			D					0		SR			0 0 0 0 0					595										0
mfsrin [1]	31			D					0 0 0 0 0					B					659										0
mtsr [1]	31			S					0		SR			0 0 0 0 0					210										0
mtsrin [1]	31			S					0 0 0 0 0					B					242										0

Table D-29. Lookaside Buffer Management Instructions

Name	0		5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
slbia [1,4,5]	31			0 0 0 0 0					0 0 0 0 0					0 0 0 0 0					498										0
slbie [1,4,5]	31			0 0 0 0 0					0 0 0 0 0					B					434										0
tlbia [1,5]	31			0 0 0 0 0					0 0 0 0 0					0 0 0 0 0					370										0
tlbie [1,5]	31			0 0 0 0 0					0 0 0 0 0					B					306										0
tlbsync [1,5]	31			0 0 0 0 0					0 0 0 0 0					0 0 0 0 0					566										0

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Table D-30. External Control Instructions

Name	0 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31
eciwx	31	D	A	B	310	0
ecowx	31	S	A	B	438	0

[1] Supervisor-level instruction
[2] Supervisor- and user-level instruction
[3] Load and store string or multiple instruction
[4] 64-bit instruction
[5] Optional in the PowerPC architecture
[6] MPC8240-implementation specific instruction

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D.4 Instructions Sorted by Form

Table D-31 through Table D-45 list the PowerPC instructions grouped by form.

Key:

Reserved bits

Instruction not implemented in the MPC8240

Table D-31. I-Form

OPCD	LI	AA	LK

Specific Instruction

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
bx	18	LI																									AA	LK

Table D-32. B-Form

OPCD	BO	BI	BD	AA	LK

Specific Instruction

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
bcx	16	BO						BI								BD											AA	LK

Table D-33. SC-Form

OPCD	00000	00000	00000000000000	1	0

Specific Instruction

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
sc	17	00000						00000								00000000000000											1	0

Table D-34. D-Form

OPCD	D	A	d
OPCD	D	A	SIMM
OPCD	S	A	d
OPCD	S	A	UIMM
OPCD	crfD 0 L	A	SIMM
OPCD	crfD 0 L	A	UIMM
OPCD	TO	A	SIMM

Specific Instructions

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
addi	14	D						A								SIMM												

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addic	12	D			A	SIMM
addic.	13	D			A	SIMM
addis	15	D			A	SIMM
andi.	28	S			A	UIMM
andis.	29	S			A	UIMM
cmpi	11	crfD	0	L	A	SIMM
cmpli	10	crfD	0	L	A	UIMM
lbz	34	D			A	d
lbzu	35	D			A	d
lfd[7]	50	D			A	d
lfdu [7]	51	D			A	d
lfs[7]	48	D			A	d
lfsu[7]	49	D			A	d
lha	42	D			A	d
lhau	43	D			A	d
lhz	40	D			A	d
lhzu	41	D			A	d
lmw [3]	46	D			A	d
lwz	32	D			A	d
lwzu	33	D			A	d
mulli	7	D			A	SIMM
ori	24	S			A	UIMM
oris	25	S			A	UIMM
stb	38	S			A	d
stbu	39	S			A	d
stfd[7]	54	S			A	d
stfdu[7]	55	S			A	d
stfs[7]	52	S			A	d
stfsu[7]	53	S			A	d
sth	44	S			A	d
sthu	45	S			A	d
stmw [3]	47	S			A	d
stw	36	S			A	d
stwu	37	S			A	d

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subfic	08	D	A	SIMM
tdi [4]	02	TO	A	SIMM
twi	03	TO	A	SIMM
xori	26	S	A	UIMM
xoris	27	S	A	UIMM

Table D-35. DS-Form

OPCD	D	A	ds	XO
OPCD	S	A	ds	XO

Specific Instructions

Name	0 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20 21 22 23 24 25 26 27 28 29	30 31
ld [4]	58	D	A	ds	0
ldu [4]	58	D	A	ds	1
lwa [4]	58	D	A	ds	2
std [4]	62	S	A	ds	0
stdu [4]	62	S	A	ds	1

Table D-36. X-Form

OPCD	D	A	B	XO	0
OPCD	D	A	NB	XO	0
OPCD	D	0 0 0 0 0	B	XO	0
OPCD	D	0 0 0 0 0	0 0 0 0 0	XO	0
OPCD	D	0 SR	0 0 0 0 0	XO	0
OPCD	S	A	B	XO	Rc
OPCD	S	A	B	XO	1
OPCD	S	A	B	XO	0
OPCD	S	A	NB	XO	0
OPCD	S	A	0 0 0 0 0	XO	Rc
OPCD	S	0 0 0 0 0	B	XO	0
OPCD	S	0 0 0 0 0	0 0 0 0 0	XO	0
OPCD	S	0 SR	0 0 0 0 0	XO	0
OPCD	S	A	SH	XO	Rc
OPCD	crfD 0 L	A	B	XO	0
OPCD	crfD 0 0	A	B	XO	0
OPCD	crfD 0 0	crfS 0 0	0 0 0 0 0	XO	0

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OPCD	crfD	0 0	0 0 0 0 0	0 0 0 0 0	XO	0
OPCD	crfD	0 0	0 0 0 0 0	IMM 0	XO	Rc
OPCD	TO		A	B	XO	0
OPCD	D		0 0 0 0 0	B	XO	Rc
OPCD	D		0 0 0 0 0	0 0 0 0 0	XO	Rc
OPCD	crbD		0 0 0 0 0	0 0 0 0 0	XO	Rc
OPCD	0 0 0 0 0		A	B	XO	0
OPCD	0 0 0 0 0		0 0 0 0 0	B	XO	0
OPCD	0 0 0 0 0		0 0 0 0 0	0 0 0 0 0	XO	0

Specific Instructions

andx	31	S	A	B	28	Rc
andcx	31	S	A	B	60	Rc
cmp	31	crfD 0 L	A	B	0	0
cmpl	31	crfD 0 L	A	B	32	0
cntlzdx [4]	31	S	A	0 0 0 0 0	58	Rc
cntlzwx	31	S	A	0 0 0 0 0	26	Rc
dcbf	31	0 0 0 0 0	A	B	86	0
dcbi [1]	31	0 0 0 0 0	A	B	470	0
dcbst	31	0 0 0 0 0	A	B	54	0
dcbt	31	0 0 0 0 0	A	B	278	0
dcbtst	31	0 0 0 0 0	A	B	246	0
dcbz	31	0 0 0 0 0	A	B	1014	0
eciwx	31	D	A	B	310	0
ecowx	31	S	A	B	438	0
eieio	31	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	854	0
eqvx	31	S	A	B	284	Rc
extsbx	31	S	A	0 0 0 0 0	954	Rc
extshx	31	S	A	0 0 0 0 0	922	Rc
extswx [4]	31	S	A	0 0 0 0 0	986	Rc
fabsx	63	D	0 0 0 0 0	B	264	Rc
fcfidx [4,7]	63	D	0 0 0 0 0	B	846	Rc
fcmpo [7]	63	crfD 0 0	A	B	32	0
fcmpu [7]	63	crfD 0 0	A	B	0	0
fctidx [4,7]	63	D	0 0 0 0 0	B	814	Rc

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fctidzx [4,7]	63	D	0 0 0 0 0	B	815	Rc
fctiwx	63	D	0 0 0 0 0	B	14	Rc
fctiwZx [7]	63	D	0 0 0 0 0	B	15	Rc
fmrx	63	D	0 0 0 0 0	B	72	Rc
fnabsx	63	D	0 0 0 0 0	B	136	Rc
fnegx	63	D	0 0 0 0 0	B	40	Rc
frspx	63	D	0 0 0 0 0	B	12	Rc
icbi	31	0 0 0 0 0	A	B	982	0
lbzux	31	D	A	B	119	0
lbzx	31	D	A	B	87	0
ldarx [4]	31	D	A	B	84	0
ldux [4]	31	D	A	B	53	0
ldx [4]	31	D	A	B	21	0
lfdux [7]	31	D	A	B	631	0
lfdx [7]	31	D	A	B	599	0
lfsux [7]	31	D	A	B	567	0
lfsx [7]	31	D	A	B	535	0
lhaux	31	D	A	B	375	0
lhax	31	D	A	B	343	0
lhbrx	31	D	A	B	790	0
lhzux	31	D	A	B	311	0
lhzx	31	D	A	B	279	0
lswi [3]	31	D	A	NB	597	0
lswx [3]	31	D	A	B	533	0
lwarx	31	D	A	B	20	0
lwaux [4]	31	D	A	B	373	0
lwax [4]	31	D	A	B	341	0
lwbrx	31	D	A	B	534	0
lwzux	31	D	A	B	55	0
lwzx	31	D	A	B	23	0
mcrfs	63	crfD 0 0	crfS 0 0	0 0 0 0 0	64	0
mcrxr	31	crfD 0 0	0 0 0 0 0	0 0 0 0 0	512	0
mfcr	31	D	0 0 0 0 0	0 0 0 0 0	19	0
mffsx	63	D	0 0 0 0 0	0 0 0 0 0	583	Rc

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mfmsr [1]	31	D	0 0 0 0 0	0 0 0 0 0	83	0
mfsr [1]	31	D	0 SR	0 0 0 0 0	595	0
mfsrin [1]	31	D	0 0 0 0 0	B	659	0
mtfsb0x [7]	63	crbD	0 0 0 0 0	0 0 0 0 0	70	Rc
mtfsb1x [7]	63	crfD	0 0 0 0 0	0 0 0 0 0	38	Rc
mtfsfix	63	crbD 0 0	0 0 0 0 0	IMM 0	134	Rc
mtmsr [1]	31	S	0 0 0 0 0	0 0 0 0 0	146	0
mtsr [1]	31	S	0 SR	0 0 0 0 0	210	0
mtsrin [1]	31	S	0 0 0 0 0	B	242	0
nandx	31	S	A	B	476	Rc
norx	31	S	A	B	124	Rc
orx	31	S	A	B	444	Rc
orcx	31	S	A	B	412	Rc
slbia [1,4,5]	31	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	498	0
slbie [1,4,5]	31	0 0 0 0 0	0 0 0 0 0	B	434	0
sldx [4]	31	S	A	B	27	Rc
slwx	31	S	A	B	24	Rc
sradx [4]	31	S	A	B	794	Rc
srawx	31	S	A	B	792	Rc
srawix	31	S	A	SH	824	Rc
srdx [4]	31	S	A	B	539	Rc
srwx	31	S	A	B	536	Rc
stbux	31	S	A	B	247	0
stbx	31	S	A	B	215	0
stdcx [4]	31	S	A	B	214	1
stdux [4]	31	S	A	B	181	0
stdx [4]	31	S	A	B	149	0
stfdux [7]	31	S	A	B	759	0
stfdx [7]	31	S	A	B	727	0
stfiwx [5,7]	31	S	A	B	983	0
stfsux [7]	31	S	A	B	695	0
stfsx [7]	31	S	A	B	663	0
sthbrx	31	S	A	B	918	0
sthux	31	S	A	B	439	0

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sthx	31	S	A	B	407	0
stswi [3]	31	S	A	NB	725	0
stswx [3]	31	S	A	B	661	0
stwbrx	31	S	A	B	662	0
stwcx	31	S	A	B	150	1
stwux	31	S	A	B	183	0
stwx	31	S	A	B	151	0
sync	31	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	598	0
td [4]	31	TO	A	B	68	0
tlbia [1,5]	31	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	370	0
tlbie [1,5]	31	0 0 0 0 0	0 0 0 0 0	B	306	0
tlbsync[1,5]	31	0 0 0 0 0	0 0 0 0 0	0 0 0 0 0	566	0
tw	31	TO	A	B	4	0
xorx	31	S	A	B	316	Rc

Table D-37. XL-Form

OPCD	BO		BI		0 0 0 0 0	XO	LK
OPCD	crbD		crbA		crbB	XO	0
OPCD	crfD	0 0	crfS	0 0	0 0 0 0 0	XO	0
OPCD	0 0 0 0 0		0 0 0 0 0		0 0 0 0 0	XO	0

Specific Instructions

Name	0 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25 26 27 28 29 30	31
bcctrx	19	BO	BI	0 0 0 0 0	528	LK
bclrx	19	BO	BI	0 0 0 0 0	16	LK
crand	19	crbD	crbA	crbB	257	0
crandc	19	crbD	crbA	crbB	129	0
creqv	19	crbD	crbA	crbB	289	0
crnand	19	crbD	crbA	crbB	225	0
crnor	19	crbD	crbA	crbB	33	0
cror	19	crbD	crbA	crbB	449	0
crorc	19	crbD	crbA	crbB	417	0
crxor	19	crbD	crbA	crbB	193	0

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isync	19	0 0 0 0 0		0 0 0 0 0		0 0 0 0 0	150	0
mcrf	19	crfD	0 0	crfS	0 0	0 0 0 0 0	0	0
rfi [1]	19	0 0 0 0 0		0 0 0 0 0		0 0 0 0 0	50	0

Table D-38. XFX-Form

OPCD	D	spr				XO	0
OPCD	D	0	CRM		0	XO	0
OPCD	S	spr				XO	0
OPCD	D	tbr				XO	0

Specific Instructions

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
mfspr [2]	31	D					spr										339	0										
mftb	31	D					tbr										371	0										
mtcrf	31	S					0	CRM								0	144	0										
mtspr [2]	31	D					spr										467	0										

Table D-39. XFL-Form

OPCD	0	FM	0	B	XO	Rc

Specific Instructions

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
mtfsfx [7]	63	0					FM					0	B					711										Rc

Table D-40. XS-Form

OPCD	S	A	sh	XO	sh	Rc

Specific Instructions

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
sradix [4]	31	S					A						sh					413									sh	Rc

Table D-41. XO-Form

OPCD	D	A	B	OE	XO	Rc
OPCD	D	A	B	0	XO	Rc
OPCD	D	A	0 0 0 0 0	OE	XO	Rc

Specific Instructions

Name	0	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
addx	31	D					A						B					OE	266									Rc

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addcx	31	D	A	B	OE	10	Rc
addex	31	D	A	B	OE	138	Rc
addmex	31	D	A	0 0 0 0 0	OE	234	Rc
addzex	31	D	A	0 0 0 0 0	OE	202	Rc
divdx [4]	31	D	A	B	OE	489	Rc
divdux [4]	31	D	A	B	OE	457	Rc
divwx	31	D	A	B	OE	491	Rc
divwux	31	D	A	B	OE	459	Rc
mulhdx [4]	31	D	A	B	0	73	Rc
mulhdux [4]	31	D	A	B	0	9	Rc
mulhwx	31	D	A	B	0	75	Rc
mulhwux	31	D	A	B	0	11	Rc
mulldx [4]	31	D	A	B	OE	233	Rc
mullwx	31	D	A	B	OE	235	Rc
negx	31	D	A	0 0 0 0 0	OE	104	Rc
subfx	31	D	A	B	OE	40	Rc
subfcx	31	D	A	B	OE	8	Rc
subfex	31	D	A	B	OE	136	Rc
subfmex	31	D	A	0 0 0 0 0	OE	232	Rc
subfzex	31	D	A	0 0 0 0 0	OE	200	Rc

Table D-42. A-Form

OPCD	D	A	B	0 0 0 0 0	XO	Rc
OPCD	D	A	B	C	XO	Rc
OPCD	D	A	0 0 0 0 0	C	XO	Rc
OPCD	D	0 0 0 0 0	B	0 0 0 0 0	XO	Rc

Specific Instructions

Name	0 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25	26 27 28 29 30	31
faddx	63	D	A	B	0 0 0 0 0	21	Rc
faddsx	59	D	A	B	0 0 0 0 0	21	Rc
fdivx	63	D	A	B	0 0 0 0 0	18	Rc
fdivsx	59	D	A	B	0 0 0 0 0	18	Rc
fmaddx	63	D	A	B	C	29	Rc
fmaddsx	59	D	A	B	C	29	Rc

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fmsubx	63	D	A	B	C	28	Rc
fmsubSx	59	D	A	B	C	28	Rc
fmulx	63	D	A	0 0 0 0 0	C	25	Rc
fmulSx	59	D	A	0 0 0 0 0	C	25	Rc
fnmaddx [7]	63	D	A	B	C	31	Rc
fnmaddSx	59	D	A	B	C	31	Rc
fnmsubx [7]	63	D	A	B	C	30	Rc
fnmsubSx	59	D	A	B	C	30	Rc
fresx [5'7]	59	D	0 0 0 0 0	B	0 0 0 0 0	24	Rc
frsqrtex [5,7]	63	D	0 0 0 0 0	B	0 0 0 0 0	26	Rc
fselx [5.7]	63	D	A	B	C	23	Rc
fsqrtx [5,7]	63	D	0 0 0 0 0	B	0 0 0 0 0	22	Rc
fsqrtsx [5,7]	59	D	0 0 0 0 0	B	0 0 0 0 0	22	Rc
fsubx	63	D	A	B	0 0 0 0 0	20	Rc
fsubsx	59	D	A	B	0 0 0 0 0	20	Rc

Table D-43. M-Form

OPCD	S	A	SH	MB	ME	Rc
OPCD	S	A	B	MB	ME	Rc

Specific Instructions

Name	0 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25	26 27 28 29 30	31
rlwimix	20	S	A	SH	MB	ME	Rc
rlwinmx	21	S	A	SH	MB	ME	Rc
rlwnmx	23	S	A	B	MB	ME	Rc

Table D-44. MD-Form

OPCD	S	A	sh	mb	XO	sh	Rc
OPCD	S	A	sh	me	XO	sh	Rc

Specific Instructions

Name	0 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25	26 27 28 29	30	31
rldicx [4]	30	S	A	sh	mb	2	sh	Rc
rldiclx [4]	30	S	A	sh	mb	0	sh	Rc
rldicrx [4]	30	S	A	sh	me	1	sh	Rc
rldimix [4]	30	S	A	sh	mb	3	sh	Rc

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Table D-45. MDS-Form

OPCD	S	A	B	mb	XO	Rc
OPCD	S	A	B	me	XO	Rc

Specific Instructions

Name	0 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25	26 27 28 29 30	31
rldclx [4]	30	S	A	B	mb	8	Rc
rldcrx [4]	30	S	A	B	me	9	Rc

[1] Supervisor-level instruction
[2] Supervisor- and user-level instruction
[3] Load and store string or multiple instruction
[4] 64-bit instruction
[5] Optional in the PowerPC architecture
[6] MPC8240-implementation specific instruction

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D.5 Instruction Set Legend

Table D-46 provides general information on the PowerPC instruction set (such as the architectural level, privilege level, and form).

Key:

Reserved bits

Instruction not implemented in the MPC8240

Table D-46. PowerPC Instruction Set Legend

	UISA	VEA	OEA	Supervisor Level	64-Bit	Optional	Form
addx	√						XO
addcx	√						XO
addex	√						XO
addi	√						D
addic	√						D
addic.	√						D
addis	√						D
addmex	√						XO
addzex	√						XO
andx	√						X
andcx	√						X
andi.	√						D
andis.	√						D
bx	√						I
bcx	√						B
bcctrx	√						XL
bclrx	√						XL
cmp	√						X
cmpi	√						D
cmpl	√						X
cmpli	√						D
cntlzdx [4]	√				√		X
cntlzwx	√						X
crand	√						XL
crandc	√						XL
creqv	√						XL
crnand	√						XL
crnor	√						XL
cror	√						XL

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Table D-46. PowerPC Instruction Set Legend (Continued)

	UISA	VEA	OEA	Supervisor Level	64-Bit	Optional	Form
crorc	√						XL
crxor	√						XL
dcbf		√					X
dcbi [1]			√	√			X
dcbst		√					X
dcbt		√					X
dcbtst		√					X
dcbz		√					X
divdx [4]	√				√		XO
divdux[4]	√				√		XO
divwx	√						XO
divwux	√						XO
eciwx		√				√	X
ecowx		√				√	X
eieio		√					X
eqvx	√						X
extsbx	√						X
extshx	√						X
extswx [4]	√				√		X
fabsx	√						X
faddx	√						A
faddsx	√						A
fcfidx [4,7]	√				√		X
fcmpo[7]	√						X
fcmpu[7]	√						X
fctidx [4,7]	√				√		X
fctidzx [7,4]	√				√		X
fctiwx	√						X
fctiwzx	√						X
fdivx	√						A
fdivsx	√						A
fmaddx	√						A
fmaddsx[7]	√						A
fmrx	√						X
fmsubx	√						A
fmsubsx[7]	√						A

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Table D-46. PowerPC Instruction Set Legend (Continued)

	UISA	VEA	OEA	Supervisor Level	64-Bit	Optional	Form
fmulx	√						A
fmulsx	√						A
fnabsx [7]	√						X
fnegx	√						X
fnmaddx [7]	√						A
fnmaddSx	√						A
fnmsubx	√						A
fnmsubsx	√						A
fresx [5,7]	√					√	A
frspx	√						X
frsqrtex [5,7]	√					√	A
fselx [5,7]	√					√	A
fsqrtx [7]	√					√	A
fsqrtsx [5,7]	√					√	A
fsubx	√						A
fsubsx	√						A
icbi		√					X
isync		√					XL
lbz	√						D
lbzu	√						D
lbzux	√						X
lbzx	√						X
ld [4]	√				√		DS
ldarx [4]	√				√		X
ldu [4]	√				√		DS
ldux [4]	√				√		X
ldx [4]	√				√		X
lfd [7]	√						D
lfdu [7]	√						D
lfdux [7]	√						X
lfdx [7]	√						X
lfs [7]	√						D
lfsu [7]	√						D
lfsux [7]	√						X
lfsx [7]	√						X
lha	√						D

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Table D-46. PowerPC Instruction Set Legend (Continued)

	UISA	VEA	OEA	Supervisor Level	64-Bit	Optional	Form
lhau	√						D
lhaux	√						X
lhax	√						X
lhbrx	√						X
lhz	√						D
lhzu	√						D
lhzux	√						X
lhzx	√						X
lmw [3]	√						D
lswi [3]	√						X
lswx [3]	√						X
lwa [4]	√				√		DS
lwarx	√						X
lwaux [4]	√				√		X
lwax [4]	√				√		X
lwbrx	√						X
lwz	√						D
lwzu	√						D
lwzux	√						X
lwzx	√						X
mcrf	√						XL
mcrfs [7]	√						X
mcrxr	√						X
mfcr	√						X
mffsx	√						X
mfmsr [1]			√	√			X
mfspr [2]	√		√	√			XFX
mfsr [1]			√	√			X
mfsrin [1]			√	√			X
mftb		√					XFX
mtcrf	√						XFX
mtfsb0x	√						X
mtfsb1x [7]	√						X
mtfsfx	√						XFL
mtfsfix	√						X
mtmsr [1]			√	√			X

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Table D-46. PowerPC Instruction Set Legend (Continued)

	UISA	VEA	OEA	Supervisor Level	64-Bit	Optional	Form
mtspr [2]	√		√	√			XFX
mtsr [1]			√	√			X
mtsrin [1]			√	√			X
mulhdx [4]	√				√		XO
mulhdux [4]	√				√		XO
mulhwx	√						XO
mulhwux	√						XO
mulldx [4]	√				√		XO
mulli	√						D
mullwx	√						XO
nandx	√						X
negx	√						XO
norx	√						X
orx	√						X
orcx	√						X
ori	√						D
oris	√						D
rfi [1]			√	√			XL
rldclx[4]	√				√		MDS
rldcrx[4]	√				√		MDS
rldicx[4]	√				√		MD
rldiclx[4]	√				√		MD
rldicrx [4]	√				√		MD
rldimix [4]	√				√		MD
rlwimix	√						M
rlwinmx	√						M
rlwnmx	√						M
sc	√		√				SC
slbia [1,4,5]			√	√	√	√	X
slbie [1,4,5]			√	√	√	√	X
sldx [4]	√				√		X
slwx	√						X
sradx [4]	√				√		X
sradix [4]	√				√		XS
srawx	√						X
srawix	√						X

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Table D-46. PowerPC Instruction Set Legend (Continued)

	UISA	VEA	OEA	Supervisor Level	64-Bit	Optional	Form
srdx [4]	√				√		X
srwx	√						X
stb	√						D
stbu	√						D
stbux	√						X
stbx	√						X
std [4]	√				√		DS
stdcx. [4]	√				√		X
stdu [4]	√				√		DS
stdux [4]	√				√		X
stdx [4]	√				√		X
stfd[7]	√						D
stfdu[7]	√						D
stfdux[7]	√						X
stfdx[7]	√						X
stfiwx [5,7]	√					√	X
stfs[7]	√						D
stfsu[7]	√						D
stfsux[7]	√						X
stfsx[7]	√						X
sth	√						D
sthbrx	√						X
sthu	√						D
sthux	√						X
sthx	√						X
stmw [3]	√						D
stswi [3]	√						X
stswx [3]	√						X
stw	√						D
stwbrx	√						X
stwcx.	√						X
stwu	√						D
stwux	√						X
stwx	√						X
subfx	√						XO
subfcx	√						XO

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Table D-46. PowerPC Instruction Set Legend (Continued)

	UISA	VEA	OEA	Supervisor Level	64-Bit	Optional	Form
subfex	√						XO
subfic	√						D
subfmex	√						XO
subfzex	√						XO
sync	√						X
td [4]	√				√		X
tdi [4]	√				√		D
tlbia [1,5]			√	√		√	X
tlbie [1,5]			√	√		√	X
tlbld [1,6]				√			X
tlbli [1,6]				√			X
tlbsync [1,5]			√	√			X
tw	√						X
twi	√						D
xorx	√						X
xori	√						D
xoris	√						D

[1] Supervisor-level instruction
[2] Supervisor- and user-level instruction
[3] Load and store string or multiple instruction
[4] 64-bit instruction
[5] Optional in the PowerPC architecture
[6] MPC8240-implementation specific instruction

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Appendix E
Processor Core Register Summary

This appendix summarizes the register set in the processor core of the MPC8240 as defined by the three programming environments of the PowerPC architecture—the user instruction set architecture (UISA), the virtual environment architecture (VEA), and the operating environment architecture (OEA), as well as the implementation-specific registers from the MPC603e and the MPC8240-specific registers.

The register formats and bit descriptions in this appendix are intended only as a reference. There are many details important for the programming of the processor core registers, such as synchronization requirements and bit interactions, that are not supplied here. Full descriptions of the basic register set defined by the PowerPC architecture are provided in Chapter 2, "PowerPC Register Set," in *The Programming Environments Manual*. Additionally, more complete descriptions of the processor core registers that are part of the MPC603e are provided in Chapter 2, "Programming Model," in the *MPC603e User's Manual*. See those references for important details about the registers and individual bits.

E.1 PowerPC Register Set

The PowerPC architecture defines register-to-register operations for all computational instructions. Source data for these instructions is accessed from the on-chip registers or is provided as an immediate value embedded in the opcode. The three-register instruction format allows specification of a target register distinct from the two source registers, thus preserving the original data for use by other instructions and reducing the number of instructions required for certain operations. Data is transferred between memory and registers with explicit load and store instructions only.

Figure E-1 shows the complete MPC8240 register set and the programming environment to which each register belongs. This figure includes both the PowerPC register set and the MPC8240-specific registers.

Note that there may be registers common to other PowerPC processors that are not implemented in the MPC8240's processor core. Unsupported special purpose register (SPR) values are treated as follows:

- Any **mtspr** with an invalid SPR executes as a no-op.
- Any **mfspr** with an invalid SPR causes boundedly undefined results in the target register.

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Conversely, some SPRs in the processor core may not be implemented at all or may not be implemented in the same way in other PowerPC processors.

E.1.1 PowerPC Register Set—UISA

The PowerPC UISA registers, shown in Figure E-1, can be accessed by either user- or supervisor-level instructions. The general-purpose registers (GPRs) and floating-point registers (FPRs) are accessed through instruction operands. Access to registers can be explicit (that is, through the use of specific instructions for that purpose such as the **mtspr** and **mfspr** instructions) or implicit as part of the execution (or side effect) of an instruction. Some registers are accessed both explicitly and implicitly.

The number to the right of the register name indicates the decimal number that is used in the syntax of the instruction operands to access the register (for example, the number used to access the XER is one).

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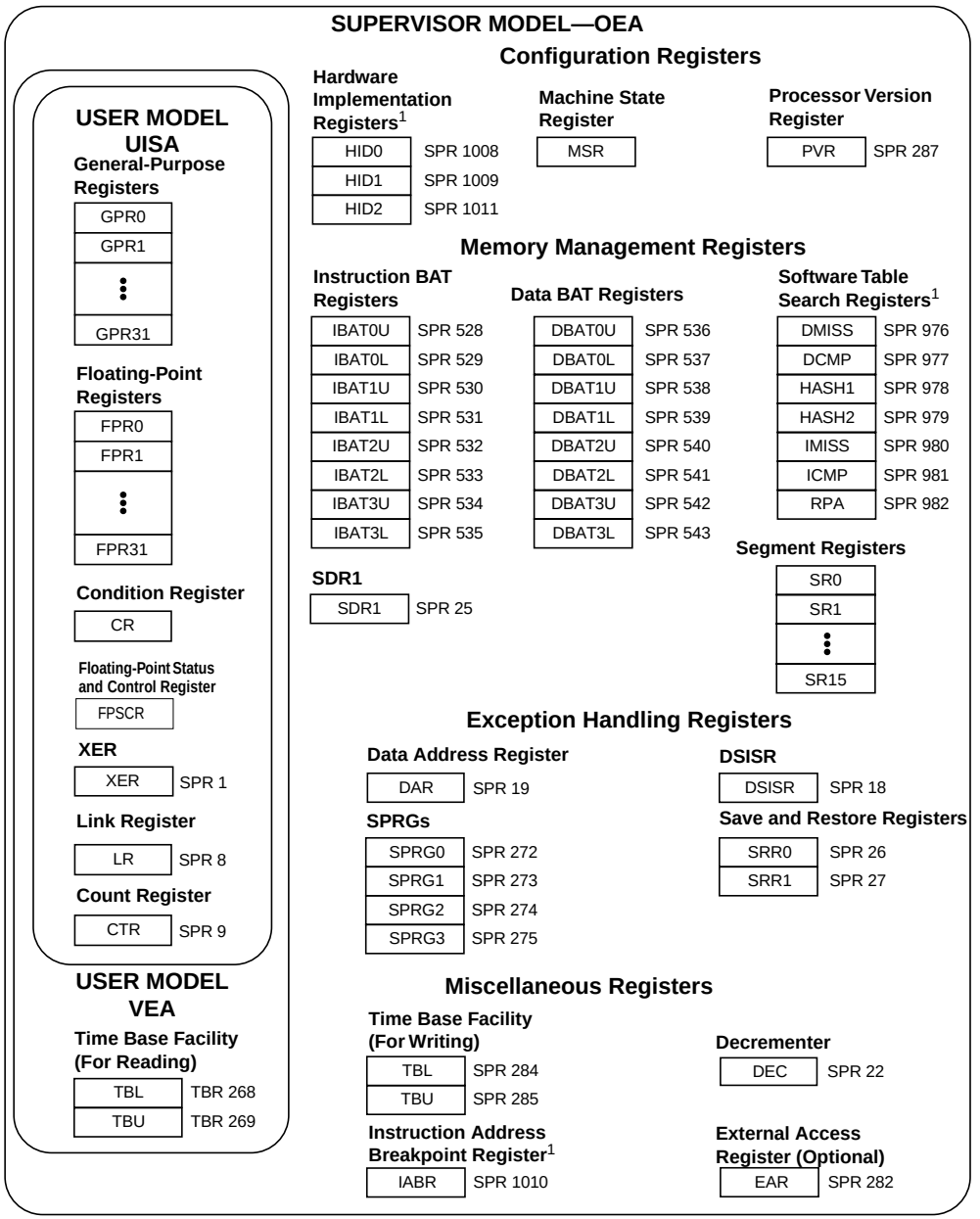

[1] These implementation–specific registers may not be supported by other PowerPC processors or processor cores.

Figure E-1. MPC8240 Processor Programming Model—Registers

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E.1.1.1 General-Purpose Registers (GPRs)

Integer data is manipulated in the processor's 32 GPRs shown in Figure E-2. The GPRs are accessed as source and destination registers in the instruction syntax.

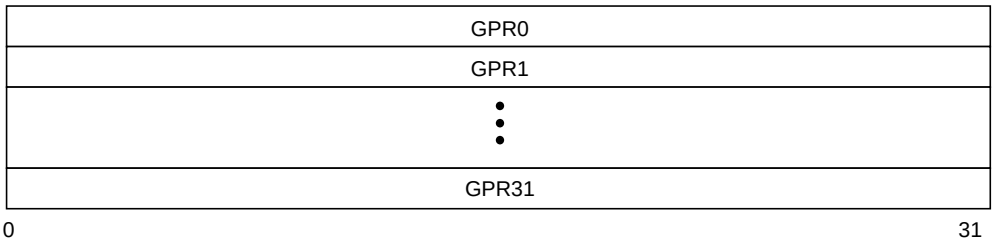

Figure E-2. General-Purpose Registers (GPRs)

E.1.1.2 Floating-Point Registers (FPRs)

The PowerPC architecture provides thirty-two 64-bit FPRs as shown in Figure E-3.

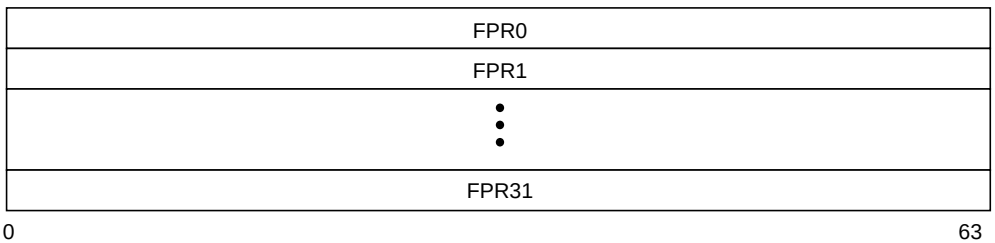

Figure E-3. Floating-Point Registers (FPRs)

E.1.1.3 Condition Register (CR)

The bits in the CR are grouped into eight 4-bit fields, CR0–CR7, as shown in Figure E-4.

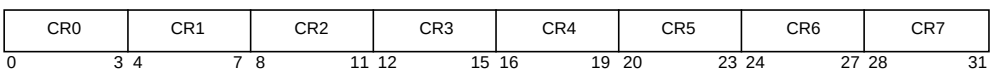

Figure E-4. Condition Register (CR)

E.1.1.3.1 Condition Register CR0 Field Definition

The CR0 bits are interpreted as shown in Table E-1.

Table E-1. Bit Settings for CR0 Field of CR

CR0 Bit	Description
0	Negative (LT)—This bit is set when the result is negative.
1	Positive (GT)—This bit is set when the result is positive (and not zero).

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Table E-1. Bit Settings for CR0 Field of CR (Continued)

CR0 Bit	Description
2	Zero (EQ)—This bit is set when the result is zero.
3	Summary overflow (SO)—This is a copy of the final state of XER[SO] at the completion of the instruction.

E.1.1.3.2 Condition Register CR1 Field Definition

The bit settings for the CR1 field are shown in Table E-2.

Table E-2. Bit Settings for CR1 Field of CR

CR1 Bit	Description
4	Floating-point exception (FX)—This is a copy of the final state of FPSCR[FX] at the completion of the instruction.
5	Floating-point enabled exception (FEX)—This is a copy of the final state of FPSCR[FEX] at the completion of the instruction.
6	Floating-point invalid exception (VX)—This is a copy of the final state of FPSCR[VX] at the completion of the instruction.
7	Floating-point overflow exception (OX)—This is a copy of the final state of FPSCR[OX] at the completion of the instruction.

E.1.1.3.3 Condition Register CRn Field—Compare Instruction

For a compare instruction the bits of the specified field are interpreted as shown in Table E-3.

Table E-3. CRn Field Bit Settings for Compare Instructions

CRn Bit[1]	Description
0	Less than or floating-point less than (LT, FL). For integer compare instructions: **r**A < SIMM or **r**B (signed comparison) or **r**A < UIMM or **r**B (unsigned comparison). For floating-point compare instructions: **fr**A < **fr**B.
1	Greater than or floating-point greater than (GT, FG). For integer compare instructions: **r**A > SIMM or **r**B (signed comparison) or **r**A > UIMM or **r**B (unsigned comparison). For floating-point compare instructions: **fr**A > **fr**B.
2	Equal or floating-point equal (EQ, FE). For integer compare instructions: **r**A = SIMM, UIMM, or **r**B. For floating-point compare instructions: **fr**A = **fr**B.
3	Summary overflow or floating-point unordered (SO, FU). For integer compare instructions:This is a copy of the final state of XER[SO] at the completion of the instruction. For floating-point compare instructions: One or both of **fr**A and **fr**B is a Not a Number (NaN).

Notes:[1]Here, the bit indicates the bit number in any one of the 4-bit subfields, CR0–CR7.

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E.1.1.4 Floating-Point Status and Control Register (FPSCR)

The FPSCR is shown in Figure E-5.

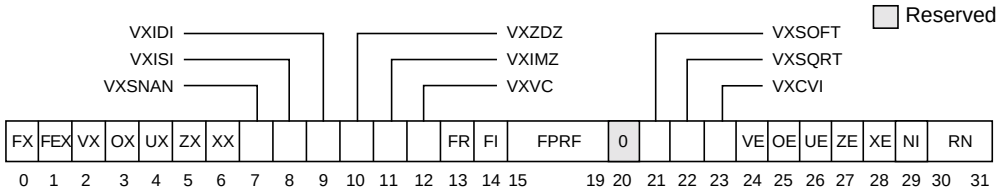
Reserved
VXIDI
VXISI
VXSNAN
VXZDZ
VXIMZ
VXVC
VXSOFT
VXSQRT
VXCVI
FX FEX VX OX UX ZX XX FR FI FPRF 0 VE OE UE ZE XE NI RN
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 19 20 21 22 23 24 25 26 27 28 29 30 31

Figure E-5. Floating-Point Status and Control Register (FPSCR)

A listing of FPSCR bit settings is shown in Table E-4.

Table E-4. FPSCR Bit Settings

Bit(s)	Name	Description
0	FX	Floating-point exception summary. Every floating-point instruction, except **mtfsfi** and **mtfsf**, implicitly sets FPSCR[FX] if that instruction causes any of the floating-point exception bits in the FPSCR to transition from 0 to 1. The **mcrfs**, **mtfsfi**, **mtfsf**, **mtfsb0**, and **mtfsb1** instructions can alter FPSCR[FX] explicitly. This is a sticky bit.
1	FEX	Floating-point enabled exception summary. This bit signals the occurrence of any of the enabled exception conditions. It is the logical OR of all the floating-point exception bits masked by their respective enable bits (FEX = (VX & VE) ^ (OX & OE) ^ (UX & UE) ^ (ZX & ZE) ^ (XX & XE)). The **mcrfs**, **mtfsf**, **mtfsfi**, **mtfsb0**, and **mtfsb1** instructions cannot alter FPSCR[FEX] explicitly. This is not a sticky bit.
2	VX	Floating-point invalid operation exception summary. This bit signals the occurrence of any invalid operation exception. It is the logical OR of all of the invalid operation exceptions. The **mcrfs**, **mtfsf**, **mtfsfi**, **mtfsb0**, and **mtfsb1** instructions cannot alter FPSCR[VX] explicitly. This is not a sticky bit.
3	OX	Floating-point overflow exception. This is a sticky bit.
4	UX	Floating-point underflow exception. This is a sticky bit.
5	ZX	Floating-point zero divide exception. This is a sticky bit.
6	XX	Floating-point inexact exception. This is a sticky bit. FPSCR[XX] is the sticky version of FPSCR[FI]. The following rules describe how FPSCR[XX] is set by a given instruction: • If the instruction affects FPSCR[FI], the new value of FPSCR[XX] is obtained by logically ORing the old value of FPSCR[XX] with the new value of FPSCR[FI]. • If the instruction does not affect FPSCR[FI], the value of FPSCR[XX] is unchanged.
7	VXSNAN	Floating-point invalid operation exception for SNaN. This is a sticky bit.
8	VXISI	Floating-point invalid operation exception for ∞ – ∞. This is a sticky bit.
9	VXIDI	Floating-point invalid operation exception for ∞ ÷ ∞. This is a sticky bit.
10	VXZDZ	Floating-point invalid operation exception for 0 ÷ 0. This is a sticky bit.
11	VXIMZ	Floating-point invalid operation exception for ∞ * 0. This is a sticky bit.
12	VXVC	Floating-point invalid operation exception for invalid compare. This is a sticky bit.
13	FR	Floating-point fraction rounded. The last arithmetic or rounding and conversion instruction that rounded the intermediate result incremented the fraction. This bit is not sticky.

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Table E-4. FPSCR Bit Settings (Continued)

Bit(s)	Name	Description
14	FI	Floating-point fraction inexact. The last arithmetic or rounding and conversion instruction either rounded the intermediate result (producing an inexact fraction) or caused a disabled overflow exception. This is not a sticky bit. For more information regarding the relationship between FPSCR[FI] and FPSCR[XX], see the description of the FPSCR[XX] bit.
15–19	FPRF	Floating-point result flags. For arithmetic, rounding, and conversion instructions, the field is based on the result placed into the target register, except that if any portion of the result is undefined, the value placed here is undefined. 15 Floating-point result class descriptor (C). Arithmetic, rounding, and conversion instructions may set this bit with the FPCC bits to indicate the class of the result as shown in Table E-5. 16–19 Floating-point condition code (FPCC). Floating-point compare instructions always set one of the FPCC bits to one and the other three FPCC bits to zero. Arithmetic, rounding, and conversion instructions may set the FPCC bits with the C bit to indicate the class of the result. Note that in this case the high-order three bits of the FPCC retain their relational significance indicating that the value is less than, greater than, or equal to zero. 16 Floating-point less than or negative (FL or <) 17 Floating-point greater than or positive (FG or >) 18 Floating-point equal or zero (FE or =) 19 Floating-point unordered or NaN (FU or ?) Note that these are not sticky bits.
20	—	Reserved
21	VXSOFT	Floating-point invalid operation exception for software request. This is a sticky bit. This bit can be altered only by the **mcrfs**, **mtfsfi**, **mtfsf**, **mtfsb0**, or **mtfsb1** instructions.
22	VXSQRT	Floating-point invalid operation exception for invalid square root. This is a sticky bit.
23	VXCVI	Floating-point invalid operation exception for invalid integer convert. This is a sticky bit.
24	VE	Floating-point invalid operation exception enable.
25	OE	IEEE floating-point overflow exception enable.
26	UE	IEEE floating-point underflow exception enable.
27	ZE	IEEE floating-point zero divide exception enable.
28	XE	Floating-point inexact exception enable.
29	NI	Floating-point non-IEEE mode. If this bit is set, results need not conform with IEEE standards and the other FPSCR bits may have meanings other than those described here. If the bit is set and if all implementation-specific requirements are met and if an IEEE-conforming result of a floating-point operation would be a denormalized number, the result produced is zero (retaining the sign of the denormalized number). Any other effects associated with setting this bit are described in the user's manual for the implementation (the effects are implementation-dependent).
30–31	RN	Floating-point rounding control. 00 Round to nearest 01 Round toward zero 10 Round toward +infinity 11 Round toward –infinity

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Table E-5 illustrates the floating-point result flags used by PowerPC processors. The result flags correspond to FPSCR bits 15–19.

Table E-5. Floating-Point Result Flags in FPSCR

Result Flags (Bits 15–19)					Result Value Class
C	<	>	=	?	
1	0	0	0	1	Quiet NaN
0	1	0	0	1	–Infinity
0	1	0	0	0	–Normalized number
1	1	0	0	0	–Denormalized number
1	0	0	1	0	–Zero
0	0	0	1	0	+Zero
1	0	1	0	0	+Denormalized number
0	0	1	0	0	+Normalized number
0	0	1	0	1	+Infinity

E.1.1.5 XER Register (XER)

The XER register (XER) is a 32-bit, user-level register shown in Figure E-6.

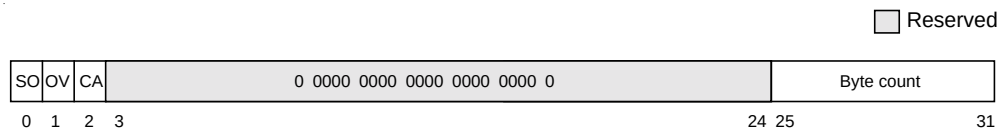

Figure E-6. XER Register

The bit definitions for XER are shown in Table E-6.

Table E-6. XER Bit Definitions

Bit(s)	Name	Description
0	SO	Summary overflow. The summary overflow bit (SO) is set whenever an instruction (except **mtspr**) sets the overflow bit (OV). Once set, the SO bit remains set until it is cleared by an **mtspr** instruction (specifying the XER) or an **mcrxr** instruction. It is not altered by compare instructions, nor by other instructions (except **mtspr** to the XER, and **mcrxr**) that cannot overflow. Executing an **mtspr** instruction to the XER, supplying the values zero for SO and one for OV, causes SO to be cleared and OV to be set.
1	OV	Overflow. The overflow bit (OV) is set to indicate that an overflow has occurred during execution of an instruction. Add, subtract from, and negate instructions having OE = 1 set the OV bit if the carry out of the msb is not equal to the carry out of the msb + 1, and clear it otherwise. Multiply low and divide instructions having OE = 1 set the OV bit if the result cannot be represented in 64 bits (**mulld**, **divd**, **divdu**) or in 32 bits (**mullw**, **divw**, **divwu**), and clear it otherwise. The OV bit is not altered by compare instructions that cannot overflow (except **mtspr** to the XER, and **mcrxr**).

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Table E-6. XER Bit Definitions (Continued)

Bit(s)	Name	Description
2	CA	Carry. The carry bit (CA) is set during execution of the following instructions: • Add carrying, subtract from carrying, add extended, and subtract from extended instructions set CA if there is a carry out of the msb, and clear it otherwise. • Shift right algebraic instructions set CA if any 1 bits have been shifted out of a negative operand, and clear it otherwise. The CA bit is not altered by compare instructions, nor by other instructions that cannot carry (except shift right algebraic, **mtspr** to the XER, and **mcrxr**).
3–24	—	Reserved
25–31		This field specifies the number of bytes to be transferred by a Load String Word Indexed (**lswx**) or Store String Word Indexed (**stswx**) instruction.

E.1.1.6 Link Register (LR)

The format of LR is shown in Figure E-7.

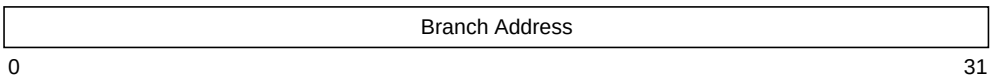

Figure E-7. Link Register (LR)

E.1.1.7 Count Register (CTR)

The CTR is shown in Figure E-8.

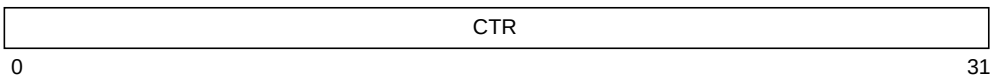

Figure E-8. Count Register (CTR)

The encoding for the BO field is shown in Table E-7.

Table E-7. BO Operand Encodings

BO	Description
0000y	Decrement the CTR, then branch if the decremented CTR ≠ 0 and the condition is FALSE.
0001y	Decrement the CTR, then branch if the decremented CTR = 0 and the condition is FALSE.
001zy	Branch if the condition is FALSE.
0100y	Decrement the CTR, then branch if the decremented CTR ≠ 0 and the condition is TRUE.
0101y	Decrement the CTR, then branch if the decremented CTR = 0 and the condition is TRUE.
011zy	Branch if the condition is TRUE.
1z00y	Decrement the CTR, then branch if the decremented CTR ≠ 0.
1z01y	Decrement the CTR, then branch if the decremented CTR = 0.

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Table E-7. BO Operand Encodings (Continued)

BO	Description
1z1zz	Branch always.

Notes: The y bit provides a hint about whether a conditional branch is likely to be taken and is used by some PowerPC implementations to improve performance. Other implementations may ignore the y bit.

The z indicates a bit that is ignored. The z bits should be cleared (zero), as they may be assigned a meaning in a future version of the PowerPC UISA.

E.1.2 PowerPC VEA Register Set—Time Base

The PowerPC virtual environment architecture (VEA) defines registers in addition to those defined by the UISA. The PowerPC VEA register set can be accessed by all software with either user- or supervisor-level privileges. Figure E-1 provides a graphic illustration of the PowerPC VEA register set included in the MPC8240.

The PowerPC VEA introduces the time base facility (TB), a 64-bit structure that consists of two 32-bit registers—time base upper (TBU) and time base lower (TBL), whose contents are incremented once every four *sys_logic_clk* cycles on the MPC8240. Note that the time base registers can be accessed by both user- and supervisor-level instructions. In the context of the VEA, user-level applications are permitted read-only access to the TB. The OEA defines supervisor-level access to the TB for writing values to the TB. See Section E.1.3.9, “Time Base Facility (TB)—OEA; Writing to the Time Base,” for more information.

The time base (TB) is shown in Figure E-9.

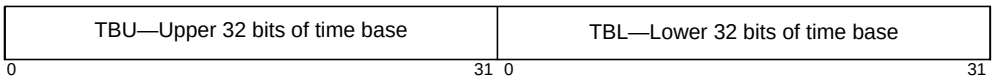

Figure E-9. Time Base (TB)

E.1.2.1 Reading the Time Base

The **mftb** instruction is used to read the time base. For information on writing the time base, see Section E.1.3.9, “Time Base Facility (TB)—OEA; Writing to the Time Base.”

On 32-bit implementations, it is not possible to read the entire 64-bit time base in a single instruction. The **mftb** simplified mnemonic moves from the lower half of the time base register (TBL) to a GPR, and the **mftbu** simplified mnemonic moves from the upper half of the time base (TBU) to a GPR.

Because of the possibility of a carry from TBL to TBU occurring between reads of the TBL and TBU, a sequence such as the following example is necessary to read the time base on 32-bit implementations:

```
loop:
        mftbu   rx      #load from TBU
        mftb    ry      #load from TBL
        mftbu   rz      #load from TBU
        cmpw    rz,rx   #see if ‘old’ = ‘new’
        bne     loop    #loop if carry occurred
```


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The comparison and loop are necessary to ensure that a consistent pair of values has been obtained. The previous example will also work on 64-bit implementations running in either 64-bit or 32-bit mode.

E.1.2.2 Computing Time of Day from the Time Base

Because the update frequency of the time base is system-dependent, the algorithm for converting the current value in the time base to time of day is also system-dependent.

In a system in which the update frequency of the time base may change over time, it is not possible to convert an isolated time base value into time of day. Instead, a time base value has meaning only with respect to the current update frequency and the time of day that the update frequency was last changed. Each time the update frequency changes, either the system software is notified of the change via an exception, or else the change was instigated by the system software itself. At each such change, the system software must compute the current time of day using the old update frequency, compute a new value of ticks-per-second for the new frequency, and save the time of day, time base value, and tick rate. Subsequent calls to compute time of day use the current time base value and the saved data.

A generalized service to compute time of day could take the following as input:

- Time of day at beginning of current epoch
- Time base value at beginning of current epoch
- Time base update frequency
- Time base value for which time of day is desired

For a PowerPC system in which the time base update frequency does not vary, the first three inputs would be constant.

E.1.3 PowerPC OEA Register Set

The PowerPC operating environment architecture (OEA) comprises the remaining PowerPC registers. The OEA defines the registers that are used typically by an operating system for such operations as memory management, configuration, and exception handling. Figure E-1 shows a graphic representation of the entire PowerPC register set—UISA, VEA, and OEA implemented on the MPC8240.

All of the registers in the OEA, including the SPRs, can be accessed only by supervisor-level instructions; any attempt to access supervisor SPRs with user-level instructions results in a supervisor-level exception. Some SPRs are implementation-specific.

Note that the GPRs, LR, CTR, TBL, MSR, DAR, SDR1, SRR0, SRR1, and SPRG0–SPRG3 are 32 bits wide on 32-bit implementations (like the MPC8240).

A summary of the PowerPC OEA supervisor-level registers in the MPC8240 follows:

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- **Configuration registers**
  - — Machine state register (MSR). The MSR defines the state of the processor. The MSR can be modified by the Move to Machine State Register (**mtmsr**), System Call (**sc**), and Return from Interrupt (**rfi**) instructions. It can be read by the Move from Machine State Register (**mfmsr**) instruction.

    Implementation Note—The 603e and MPC8240 define MSR[13] as the power management enable (POW) bit and MSR[14] as the temporary GPR remapping (TGPR) bit as shown in Table E-8.
  - — Processor version register (PVR). This register is a read-only register that identifies the version (model) and revision level of the PowerPC processor.

    Implementation Note—The MPC8240's processor version number is 0x0081; the processor revision level starts at 0x0100 and is incremented for each revision of the chip. The revision level is updated on all silicon revisions.
- **Memory management registers**
  - — Block-address translation (BAT) registers. The PowerPC OEA includes eight block-address translation registers (BATs), consisting of four pairs of instruction BATs (IBAT0U–IBAT3U and IBAT0L–IBAT3L) and four pairs of data BATs (DBAT0U–DBAT3U and DBAT0L–DBAT3L). The SPR numbers for the BAT registers are shown in Figure E-1.
  - — SDR1. The SDR1 register specifies the page table base address used in virtual-to-physical address translation.
  - — Segment registers (SR). The PowerPC OEA defines sixteen 32-bit segment registers (SR0–SR15). Note that the SRs are implemented on 32-bit implementations only. The fields in the segment register are interpreted differently depending on the value of bit 0.
- **Exception handling registers**
  - — Data address register (DAR). After a DSI or an alignment exception, DAR is set to the effective address generated by the faulting instruction.
  - — SPRG0–SPRG3. The SPRG0–SPRG3 registers are provided for operating system use.
  - — DSISR. The DSISR defines the cause of DSI and alignment exceptions.
  - — Machine status save/restore register 0 (SRR0). The SRR0 register is used to save machine status on exceptions and to restore machine status when an **rfi** instruction is executed.
  - — Machine status save/restore register 1 (SRR1). The SRR1 register is used to save machine status on exceptions and to restore machine status when an **rfi** instruction is executed.

    Implementation Note—The 603e and MPC8240 implement the Key bit (bit 12) in the SRR1 register in order to simplify the table search software.

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- **Miscellaneous registers**
  - — The time base facility (TB) for writing. The TB is a 64-bit register pair that can be used to provide time of day or interval timing. It consists of two 32-bit registers—time base upper (TBU) and time base lower (TBL). The TB is incremented once every four *sys_logic_clk* cycles.
  - — Decrementer (DEC). The DEC register is a 32-bit decrementing counter that provides a mechanism for causing a decrementer exception after a programmable delay. The DEC is decremented once every four *sys_logic_clk* cycles.
  - — External access register (EAR). This optional register is used in conjunction with the **eciwx** and **ecowx** instructions. While the PowerPC architecture specifies that the low-order six bits of the EAR (bits 26–31) are used to select a device, the 603e and MPC8240 only implement the low-order 4 bits (bits 28–31). Note that the EAR register and the **eciwx** and **ecowx** instructions are optional in the PowerPC architecture and may not be supported in all PowerPC processors that implement the OEA.

E.1.3.1 Machine State Register (MSR)

The machine state register (MSR) is shown in Figure E-10.

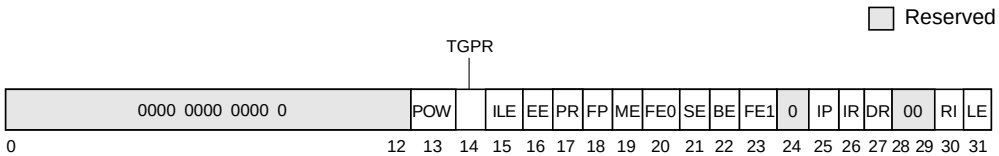

Figure E-10. Machine State Register (MSR)

Table E-8 shows the bit definitions for the MSR.

Table E-8. MSR Bit Settings

Bit(s)	Name	Reset Value	Description
0–12	—	0	Reserved
13	POW	0	Power management enable (603e-specific) 0 Power management disabled (normal operation mode) 1 Power management modes enabled (doze, nap, or sleep mode) This bit controls the programmable power modes only; it has no effect on dynamic power management (DPM). MSR[POW] may be altered with an **mtmsr** instruction only. Also, when altering the POW bit, software may alter only this bit in the MSR and no others with the same instruction. The **mtmsr** instruction must be followed by a context-synchronizing instruction.

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Table E-8. MSR Bit Settings (Continued)

Bit(s)	Name	Reset Value	Description
14	TGPR	0	Temporary GPR remapping (603e-specific) 0 Normal operation 1 TGPR mode. GPR0–GPR3 are remapped to TGPR0–TGPR3 for use by TLB miss routines. The contents of GPR0–GPR3 remain unchanged while MSR[TGPR] = 1. Attempts to use GPR4–GPR31 with MSR[TGPR] = 1 yield undefined results. When this bit is set, all instruction accesses to GPR0–GPR3 are mapped to TGPR0–TGPR3, respectively. The TGPR bit is set when an instruction TLB miss, data TLB miss on load or data TLB miss on store exception is taken. The TGPR bit is cleared by an **rfi** instruction.
15	ILE	0	Exception little-endian mode. When an exception occurs, this bit is copied into MSR[LE] to select the endian mode for the context established by the exception.
16	EE	0	External interrupt enable 0 While the bit is cleared, the processor delays recognition of external interrupts and decrementer exception conditions. 1 The processor is enabled to take an external interrupt or the decrementer exception.
17	PR	0	Privilege level 0 The processor can execute both user- and supervisor-level instructions. 1 The processor can only execute user-level instructions.
18	FP	0	Floating-point available 0 The processor prevents dispatch of floating-point instructions, including floating-point loads, stores, and moves. 1 The processor can execute floating-point instructions.
19	ME	0	Machine check enable 0 Machine check exceptions are disabled. 1 Machine check exceptions are enabled.
20	FE0	0	Floating-point exception mode 0 (see Table E-9).
21	SE	0	Single-step trace enable 0 The processor executes instructions normally. 1 The processor generates a single-step trace exception upon the successful execution of the next instruction.
22	BE	0	Branch trace enable 0 The processor executes branch instructions normally. 1 The processor generates a branch trace exception after completing the execution of a branch instruction, regardless of whether the branch was taken.
23	FE1	0	Floating-point exception mode 1 (see Table E-9).
24	—	0	Reserved
25	IP	1	Exception prefix. The setting of this bit specifies whether an exception vector offset is prepended with Fs or 0s. In the following description, nnnnn is the offset of the exception vector. 0 Exceptions are vectored to the physical address 0x000n_nnnn. 1 Exceptions are vectored to the physical address 0xFFFn_nnnn. In most systems, IP is set to 1 during system initialization, and then cleared to 0 when initialization is complete.
26	IR	0	Instruction address translation 0 Instruction address translation is disabled. 1 Instruction address translation is enabled.
27	DR	0	Data address translation 0 Data address translation is disabled. 1 Data address translation is enabled.

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Table E-8. MSR Bit Settings (Continued)

Bit(s)	Name	Reset Value	Description
28–29	—	0	Reserved
30	RI	0	Recoverable exception (for system reset and machine check exceptions). 0 Exception is not recoverable. 1 Exception is recoverable.
31	LE	0	Little-endian mode enable 0 The processor runs in big-endian mode. 1 The processor runs in little-endian mode.

The floating-point exception mode bits (FE0–FE1) are interpreted as shown in Table E-9.

Table E-9. Floating-Point Exception Mode Bits

FE0	FE1	Mode
0	0	Floating-point exceptions disabled
0	1	Floating-point imprecise nonrecoverable
1	0	Floating-point imprecise recoverable
1	1	Floating-point precise mode

E.1.3.2 Processor Version Register (PVR)

The processor version register (PVR) is a 32-bit, read-only register that contains a value identifying the specific version (model) and revision level of the PowerPC processor as shown in Figure E-11.

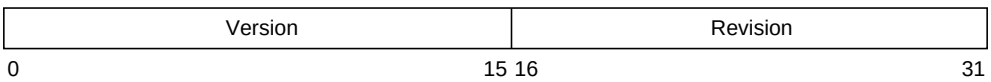

Figure E-11. Processor Version Register (PVR)

Software can identify the MPC8240's processor core by reading the processor version register (PVR). The MPC8240's processor version number is 0x0081; the processor revision level starts at 0x0100 and is incremented for each revision of the chip. This information is useful for data cache flushing routines for identifying the size of the cache and identifying this processor as one that supports cache locking.

E.1.3.3 BAT Registers

Figure E-12 and Figure E-13 show the format of the upper and lower BAT registers for 32-bit PowerPC processors.

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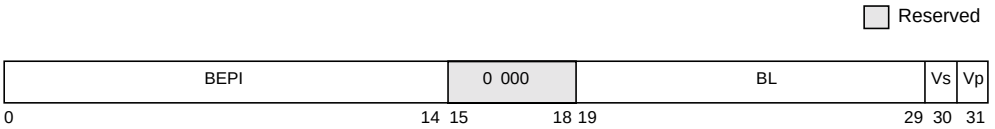
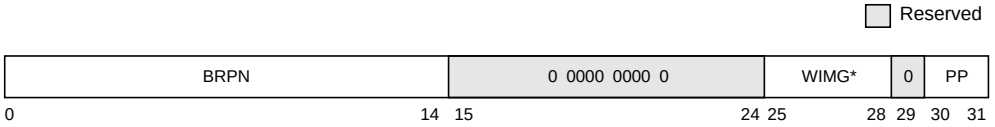


Figure E-12. Upper BAT Register



*W and G bits are not defined for IBAT registers. Attempting to write to these bits causes boundedly-undefined results.

Figure E-13. Lower BAT Register

Table E-10 describes the bits in the BAT registers.

Table E-10. BAT Registers—Field and Bit Descriptions

Upper/Lower BAT	Bits	Name	Description
Upper BAT Register	0–14	BEPI	Block effective page index. This field is compared with high-order bits of the logical address to determine if there is a hit in that BAT array entry.
	15–18	—	Reserved
	19–29	BL	Block length. BL is a mask that encodes the size of the block. Values for this field are listed in Table E-11.
	30	Vs	Supervisor mode valid bit. This bit interacts with MSR[PR] to determine if there is a match with the logical address.
	31	Vp	User mode valid bit. This bit also interacts with MSR[PR] to determine if there is a match with the logical address.
Lower BAT Register	0–14	BRPN	This field is used in conjunction with the BL field to generate high-order bits of the physical address of the block.
	15–24	—	Reserved
	25–28	WIMG	Memory/cache access mode bits W Write-through I Caching-inhibited M Memory coherence G Guarded Attempting to write to the W and G bits in IBAT registers causes boundedly-undefined results.
	29	—	Reserved
	30–31	PP	Protection bits for block. This field determines the protection for the block.

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Table E-11 lists the BAT area lengths encoded in BAT[BL].

Table E-11. BAT Area Lengths

BAT Area Length	BL Encoding
128 Kbytes	000 0000 0000
256 Kbytes	000 0000 0001
512 Kbytes	000 0000 0011
1 Mbyte	000 0000 0111
2 Mbytes	000 0000 1111
4 Mbytes	000 0001 1111
8 Mbytes	000 0011 1111
16 Mbytes	000 0111 1111
32 Mbytes	000 1111 1111
64 Mbytes	001 1111 1111
128 Mbytes	011 1111 1111
256 Mbytes	111 1111 1111

E.1.3.4 SDR1

The format of the SDR1 is shown in Figure E-14.

Figure E-14. SDR1 Register Format

The bits of SDR1 are described in Table E-12.

Table E-12. SDR1 Bit Settings

Bits	Name	Description
0–15	HTABORG	The high-order 16 bits of the 32-bit physical address of the page table
16–22	—	Reserved
23–31	HTABMASK	Mask for page table address

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E.1.3.5 Segment Registers

The segment registers, shown in Figure E-15, contain the segment descriptors.

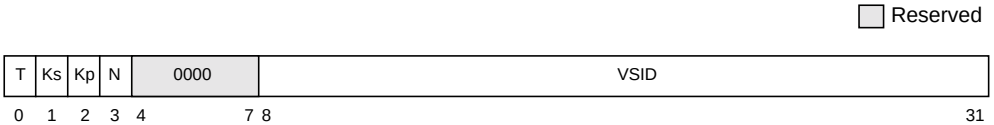

Figure E-15. Segment Register Format (T = 0)

Segment register bit settings when T = 0 are described in Table E-13.

Table E-13. Segment Register Bit Settings (T = 0)

Bits	Name	Description
0	T	T = 0 selects this format
1	Ks	Supervisor-state protection key
2	Kp	User-state protection key
3	N	No-execute protection
4–7	—	Reserved
8–31	VSID	Virtual segment ID

E.1.3.6 SPRG0–SPRG3

The format of SPRG0–SPRG3 is shown in Figure E-16.

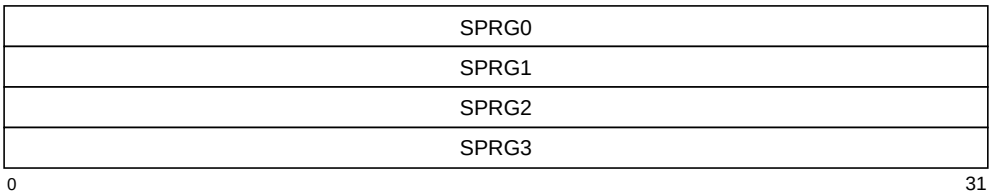

Figure E-16. SPRG0–SPRG3

Table E-14 provides a description of conventional uses of SPRG0 through SPRG3.

Table E-14. Conventional Uses of SPRG0–SPRG3

Register	Description
SPRG0	Software may load a unique physical address in this register to identify an area of memory reserved for use by the first-level exception handler. This area must be unique for each processor in the system.
SPRG1	This register may be used as a scratch register by the first-level exception handler to save the content of a GPR. That GPR then can be loaded from SPRG0 and used as a base register to save other GPRs to memory.
SPRG2	This register may be used by the operating system as needed.
SPRG3	This register may be used by the operating system as needed.

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E.1.3.7 DSISR

The 32-bit DSISR is shown in Figure E-17.

Figure E-17. DSISR

For information about bit settings, see Chapter 4, "Exceptions," in the *MPC603e User's Manual.*

E.1.3.8 Machine Status Save/Restore Register 0 (SRR0)

The format of SRR0 is shown in Figure E-18.

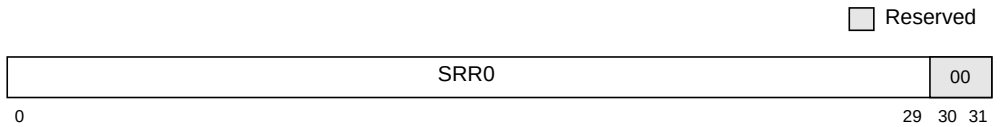

Figure E-18. Machine Status Save/Restore Register 0 (SRR0)Machine Status Save/Restore Register 1 (SRR1)

The format of SRR1 is shown in Figure E-19.

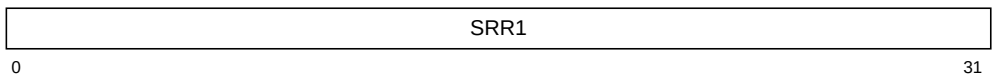

Figure E-19. Machine Status Save/Restore Register 1 (SRR1)

E.1.3.9 Time Base Facility (TB)—OEA; Writing to the Time Base

Note that writing to the TB is reserved for supervisor-level software.

The simplified mnemonics, **mttbl** and **mttbu**, write the lower and upper halves of the TB, respectively. The simplified mnemonics listed above are for the **mtspr** instruction. The **mtspr**, **mttbl**, and **mttbu** instructions treat TBL and TBU as separate 32-bit registers; setting one leaves the other unchanged. It is not possible to write the entire 64-bit time base with a single instruction.

E.1.3.10 Decrementer Register (DEC)

The decrementer register (DEC), shown in Figure E-20, is a 32-bit decrementing counter that is decremented once every four *sys_logic_clk* cycles and provides a mechanism for causing a decrementer exception after a programmable delay.

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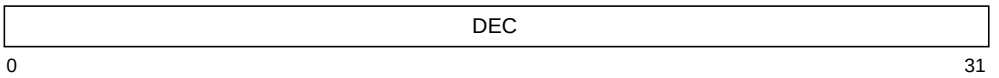

Figure E-20. Decrementer Register (DEC)

E.1.3.11 External Access Register (EAR)

The EAR is a 32-bit SPR that controls access to the external control facility and identifies the target device for external control operations. This register can also be accessed by using the **mtspr** and **mfspr** instructions. The EAR is shown in Figure E-21.

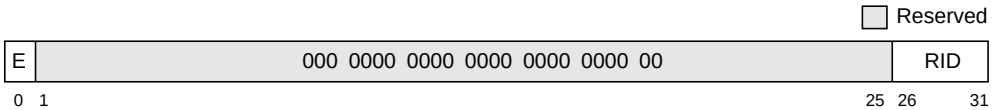

Figure E-21. External Access Register (EAR)

The bit settings for the EAR are described in Table E-15.

Table E-15. External Access Register (EAR) Bit Settings

Bit	Name	Description
0	E	Enable bit 1 Enabled 0 Disabled If this bit is set, the **eciwx** and **ecowx** instructions can perform the specified external operation. If the bit is cleared, an **eciwx** or **ecowx** instruction causes a DSI exception.
1–25	—	Reserved
26–31	RID	Resource ID

E.2 Implementation-Specific Registers from 603e

The processor core of the MPC8240 includes some implementation-specific SPRs of the 603e processor that are not defined by the PowerPC architecture. Most of these are described in the *MPC603e User's Manual* and are implemented in the MPC8240 as follows:

- MMU software table search registers—DMISS, DCMP, HASH1, HASH2, IMISS, ICMP, and RPA. These registers facilitate the software required to search the page tables in memory and should only be accessed when address translation is disabled (that is, MSR[IR] = 0 and MSR[DR] = 0).
- IABR—This register facilitates the setting of instruction breakpoints.

These registers can be accessed by supervisor-level instructions only. Any attempt to access these SPRs with user-level instructions results in a supervisor-level exception. The SPR numbers for these registers are shown in Figure E-1.

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E.2.1 Data and Instruction TLB Miss Address Registers (DMISS and IMISS)

The DMISS and IMISS registers have the same format as shown in Figure E-22. They are loaded automatically upon a data or instruction TLB miss. The DMISS and IMISS contain the effective page address of the access that caused the TLB miss exception. The contents are used by the 603e when calculating the values of HASH1 and HASH2, and by the **tlbld** and **tlbli** instructions when loading a new TLB entry. Note that the 603e always loads the DMISS register with a big-endian address, even when MSR[LE] is set. These registers can be read and written by software.

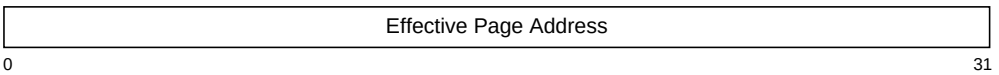

Figure E-22. DMISS and IMISS Registers

E.2.2 Data and Instruction TLB Compare Registers (DCMP and ICMP)

The DCMP and ICMP registers are shown in Figure E-23. These registers contain the first word in the required PTE. The contents are constructed automatically from the contents of the segment registers and the effective address (DMISS or IMISS) when a TLB miss exception occurs. Each PTE read from the tables during the table search process should be compared with this value to determine whether or not the PTE is a match. Upon execution of a **tlbld** or **tlbli** instruction the upper 25 bits of the DCMP or ICMP register and 11 bits of the effective address operand are loaded into the first word of the selected TLB entry. These registers can be read and written by software.

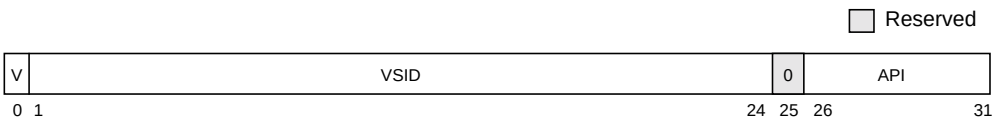

Figure E-23. DCMP and ICMP Registers

Table E-16 describes the bit settings for the DCMP and ICMP registers.

Table E-16. DCMP and ICMP Bit Settings

Bits	Name	Description
0	V	Valid bit. Set by the processor on a TLB miss exception.
1–24	VSID	Virtual segment ID. Copied from VSID field of corresponding segment register.
25	—	Reserved
26–31	API	Abbreviated page index. Copied from API of effective address.

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E.2.3 Primary and Secondary Hash Address Registers (HASH1 and HASH2)

The HASH1 and HASH2 registers contain the physical addresses of the primary and secondary PTEGs for the access that caused the TLB miss exception. For convenience, the 603e automatically constructs the full physical address by routing bits 0–6 of SDR1 into HASH1 and HASH2 and clearing the lower 6 bits. These registers are read-only and are constructed from the contents of the DMISS or IMISS register (the register choice is determined by which miss was last acknowledged). The format for the HASH1 and HASH2 registers is shown in Figure E-24.

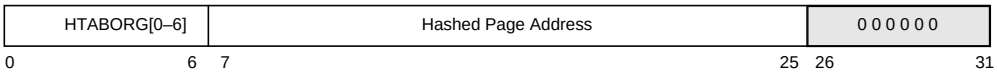

Figure E-24. HASH1 and HASH2 Registers

Table E-17 describes the bit settings of the HASH1 and HASH2 registers.

Table E-17. HASH1 and HASH2 Bit Settings

Bits	Name	Description
0–6	HTABORG[0–6]	Copy of the upper 7 bits of the HTABORG field from SDR1
7–25	Hashed page address	Address bits 7–25 of the PTEG to be searched
26–31	—	Reserved

E.2.4 Required Physical Address Register (RPA)

The RPA register is shown in Figure E-25. During a page table search operation, the software must load the RPA with the second word of the correct PTE. When the **tlbld** or **tlbli** instruction is executed, the contents of the RPA register and the DMISS or IMISS register are merged and loaded into the selected TLB entry. The referenced (R) bit is ignored when the write occurs (no location exists in the TLB entry for this bit). The RPA register can be read and written by software.

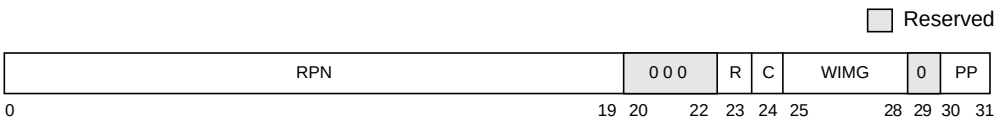

Figure E-25. Required Physical Address Register (RPA)

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Table E-18 describes the bit settings of the RPA register.

Table E-18. RPA Bit Settings

Bits	Name	Description
0–19	RPN	Physical page number from PTE
20–22	—	Reserved
23	R	Referenced bit from PTE
24	C	Changed bit from PTE
25–28	WIMG	Memory/cache access attribute bits
29	—	Reserved
30–31	PP	Page protection bits from PTE

E.2.5 Instruction Address Breakpoint Register (IABR)

The IABR, shown in Figure E-26, controls the instruction address breakpoint exception. IABR[CEA] holds an effective address to which each instruction is compared. The exception is enabled by setting bit 30 of IABR. The exception is taken when there is an instruction address breakpoint match on the next instruction to complete. The instruction tagged with the match will not be completed before the breakpoint exception is taken.

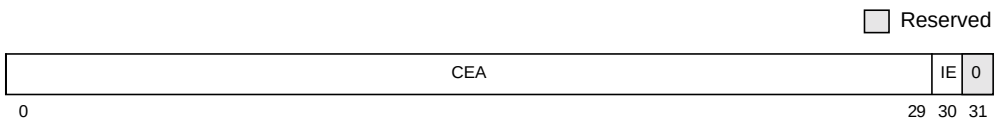

Figure E-26. Instruction Address Breakpoint Register (IABR)

The bits in the IABR are defined as shown in Table E-19.

Table E-19. Instruction Address Breakpoint Register Bit Settings

Bit	Description
0–29	Word address to be compared
30	IABR enabled. Setting this bit indicates that the IABR exception is enabled.
31	Reserved

E.3 MPC8240-Specific Registers

The hardware implementation-dependent registers (HIDx) are implemented differently in the MPC8240 as described in the following subsections.

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E.3.1 Hardware Implementation-Dependent Register 0 (HID0)

The processor core's implementation of HID0 differs from the *MPC603e User's Manual* as follows:

- Bit 5, HID0[EICE], has been removed
- No support for pipeline tracking

Figure E-27 shows the MPC8240 implementation of HID0. HID0 can be accessed with **mtspr** and **mfspr** using SPR1008.

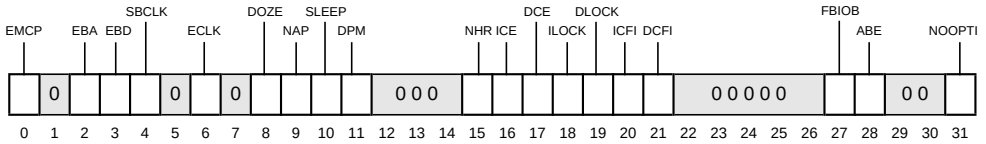

Figure E-27. Hardware Implementation Register 0 (HID0)

Table E-20 shows the bit definitions for HID0.

Table E-20. HID0 Field Descriptions

Bits	Name	Description
0	EMCP	Enable machine check internal signal 0 The assertion of the internal $\overline{\text{mcp}}$ signal from the peripheral logic does not cause a machine check exception. 1 Enables the machine check exception based on assertion of the internal $\overline{\text{mcp}}$ signal from the peripheral logic to the processor core. Note that the machine check exception is further affected by MSR[ME], which specifies whether the processor checkstops or continues processing.
1	—	Reserved
2	EBA	Enable/disable internal peripheral bus (60x bus) address parity checking 0 Prevents address parity checking 1 Allows a address parity error to cause a checkstop if MSR[ME] = 0 or a machine check exception if MSR[ME] = 1 EBA and EBD let the processor operate with memory subsystems that do not generate parity.
3	EBD	Enable internal peripheral bus (60x bus) data parity checking 0 Parity checking is disabled. 1 Allows a data parity error to cause a checkstop if MSR[ME] = 0 or a machine check exception if MSR[ME] = 1 EBA and EBD let the processor operate with memory subsystems that do not generate parity.
4	SBCLK	CKO output enable and clock type selection. When PMCR1[CKO_SEL] = 0, this bit is used in conjunction with HID0[ECLK] and the hard reset signals to configure CKO. See Table E-20.
5	—	EICE bit on some other PowerPC devices This bit is not used in the MPC8240 (and so it is reserved).
6	ECLK	CKO output enable and clock type selection.When PMCR1[CKO_SEL] = 0, this bit is used in conjunction with HID0[SBCLK] and the hard reset signals to configure CKO. See Table E-20.
7	—	PAR bit on some other PowerPC devices to disable precharge of $\overline{\text{ARTRY}}$ signal. This bit is not used in the MPC8240 (and so it is reserved).

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Table E-20. HID0 Field Descriptions (Continued)

Bits	Name	Description
8	DOZE	Doze mode enable. Operates in conjunction with MSR[POW][1] 0 Processor doze mode disabled. 1 Processor doze mode enabled. Doze mode is invoked by setting MSR[POW] while this bit is set. In doze mode, the PLL, time base, and snooping remain active.
9	NAP	Nap mode enable—Operates in conjunction with MSR[POW] [1] 0 Processor nap mode disabled 1 Processor nap mode enabled. Nap mode is invoked by setting MSR[POW] while this bit is set. When this occurs, the processor indicates that it is ready to enter nap mode. If the peripheral logic determines that the processor may enter nap mode (no more snooping of the internal buffers is required), the processor enters nap mode after several processor clocks. In nap mode, the PLL and the time base remain active. Note that the MPC8240 asserts the $\overline{\text{QACK}}$ output signal depending on the power-saving state of the peripheral logic, and not on the power-saving state of the processor core.
10	SLEEP	Sleep mode enable—Operates in conjunction with MSR[POW] [1] 0 Processor sleep mode disabled. 1 Processor sleep mode enabled—Sleep mode is invoked by setting MSR[POW] while this bit is set. When this occurs, the processor indicates that it is ready to enter sleep mode. If the peripheral logic determines that the processor may enter sleep mode (no more snooping of the internal buffers is required), the processor enters sleep mode after several processor clocks. At this point, the system logic may turn off the PLL by first configuring PLL_CFG[0–4] to PLL bypass mode, and then disabling the internal sys_logic-clk signal. Note that the MPC8240 asserts the $\overline{\text{QACK}}$ output signal depending on the power-saving state of the peripheral logic, and not on the power-saving state of the processor core.
11	DPM	Dynamic power management enable [1] 0 Processor dynamic power management is disabled. 1 Functional units enter a low-power mode automatically if the unit is idle. This does not affect operational performance and is transparent to software or any external hardware.
12–14	—	Reserved
15	NHR	Not hard reset (software-use only)—Helps software distinguish a hard reset from a soft reset. 0 A hard reset occurred if software had previously set this bit. 1 A hard reset has not occurred. If software sets this bit after a hard reset, when a reset occurs and this bit remains set, software can detect that it was a soft reset.
16	ICE	Instruction cache enable [2] 0 The instruction cache is neither accessed nor updated. All pages are accessed as if they were marked cache-inhibited (WIM = X1X). Potential cache accesses from the bus (snoop and cache operations) are ignored. In the disabled state for the L1 caches, the cache tag state bits are ignored, and all accesses are propagated to the bus as single-beat transactions. For these transactions, however, the processor reflects the original state of the I bit (from the MMU) to the peripheral logic block, regardless of cache disabled status. ICE is zero at power-up. 1 The instruction cache is enabled
17	DCE	Data cache enable [2] 0 The data cache is neither accessed nor updated. All pages are accessed as if they were marked cache-inhibited (WIM = X1X). Potential cache accesses from the bus (snoop and cache operations) are ignored. In the disabled state, the cache tag state bits are ignored and all accesses are propagated to the bus as single-beat transactions. For those transactions, however, the processor reflects the original state of the I bit (from the MMU) to the peripheral logic block, regardless of cache disabled status. DCE is zero at power-up. 1 The data cache is enabled.

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Table E-20. HID0 Field Descriptions (Continued)

Bits	Name	Description
18	ILOCK	Instruction cache lock 0 Normal operation 1 Instruction cache is locked. A locked cache supplies data normally on a hit, but an access is treated as a cache-inhibited transaction on a miss. On a miss, the transaction to the bus is single-beat. To prevent locking during a cache access, an **isync** must precede the setting of ILOCK.
19	DLOCK	Data cache lock 0 Normal operation 1 Data cache is locked. A locked cache supplies data normally on a hit but an access is treated as a cache-inhibited transaction on a miss. On a miss, the transaction to the bus is single-beat. A snoop hit to a locked L1 data cache performs as if the cache were not locked. A cache block invalidated by a snoop remains invalid until the cache is unlocked. To prevent locking during a cache access, a **sync** must precede the setting of DLOCK.
20	ICFI	Instruction cache flash invalidate [2] 0 The instruction cache is not invalidated. The bit is cleared when the invalidation operation begins (usually the next cycle after the write operation to the register). The instruction cache must be enabled for the invalidation to occur. 1 An invalidate operation is issued that marks the state of each instruction cache block as invalid without writing back modified cache blocks to memory. Cache access is blocked during this time. Accesses to the cache from the peripheral logic bus are signaled as a miss during invalidate-all operations. Setting ICFI clears all the valid bits of the blocks and the PLRU bits to point to way L0 of each set. Once this flash invalidate bit is set through an **mtspr** instruction, hardware automatically resets this bit in the next cycle (provided that the corresponding cache enable bit is set in HID0).
21	DCFI	Data cache flash invalidate [2] 0 The data cache is not invalidated. The bit is cleared when the invalidation operation begins (usually the next cycle after the write operation to the register). The data cache must be enabled for the invalidation to occur. 1 An invalidate operation is issued that marks the state of each data cache block as invalid without writing back modified cache blocks to memory. Cache access is blocked during this time. Accesses to the cache from the peripheral logic bus are signaled as a miss during invalidate-all operations. Setting DCFI clears all the valid bits of the blocks and the PLRU bits so that they point to way L0 of each set. Once the flash invalidate bit is set through an **mtspr** instruction, hardware automatically resets this bit in the next cycle (provided that the corresponding cache enable bit is set in HID0).
22–23	—	Reserved
24	—	IFEM bit on some other PowerPC devices This bit is not used in the MPC8240 (and so it is reserved).
25–26	—	Reserved
27	FBIOB	Force branch indirect on bus 0 Register indirect branch targets are fetched normally 1 Forces register indirect branch targets to be fetched externally.
28	—	Reserved—Used as address broadcast enable bit on some other PowerPC devices
29–30	—	Reserved
31	NOOPTI	No-op the data cache touch instructions 0 The **dcbt** and **dcbtst** instructions are enabled. 1 The **dcbt** and **dcbtst** instructions are no-oped globally.

[1] See Chapter 9, “Power Management,” of the MPC603e User’s Manual for more information.

[2] See Chapter 3, “Instruction and Data Cache Operation,” of the MPC603e User’s Manual for more information.

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Table E-21 shows how HID0[SBCLK], HID0[ECLK], and the hard reset signals are used to configure CKO when PMCR1[CKO_SEL] = 0. When PMCR1[CKO_SEL] = 1, the CKO_MODE field of PMCR1 determines the signal driven on CKO. Note that the initial value of PMCR1[CKO_SEL] is determined by the value on the $\overline{AS}$ signal at the negation of $\overline{HRST\_CPU}$. See Section 2.2.7.8, “Debug Clock (CKO)—Output,” and Section 2.4, “Configuration Signals Sampled at Reset,” for more information.

Table E-21. HID0[BCLK] and HID0[ECLK] CKO Signal Configuration

$\overline{HRST\_CPU}$ and $\overline{HRST\_CTRL}$	HID0[ECLK]	HID0[SBCLK]	Signal Driven on CKO
Asserted	x	x	sys-logic-clk
Negated	0	0	High impedance
Negated	0	1	sys-logic-clk divided by 2
Negated	1	0	Processor core clock
Negated	1	1	sys-logic-clk

E.3.2 Hardware Implementation-Dependent Register 1 (HID1)

The MPC8240 implementation of HID1 is shown in Figure E-28. HID1 can be accessed with **mfspr** using SPR1009.

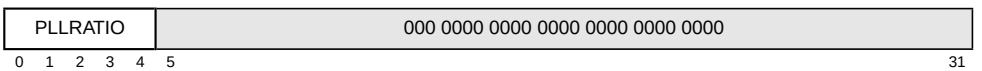

Figure E-28. Hardware Implementation Register 1 (HID1)

Table E-22 shows the bit definitions for HID1.

Table E-22. HID1 Field Descriptions

Bits	Name	Function
0–4	PLLRATIO	PLL configuration processor core frequency ratio—This read-only field is determined by the value on the PLL_CFG[0–4] signals during reset and the processor-to-memory clock frequency ratio defined by that PLL_CFG[0–4] value. See MPC8240 Hardware Specification for a listing of supported settings. Note that multiple settings of the PLL_CFG[0–4] signals can map to the same PLLRATIO value. Thus, system software cannot read the PLLRATIO value and associate it with a unique PLL_CFG[0–4] value.
5–31	—	Reserved

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E.3.3 Hardware Implementation-Dependent Register 2 (HID2)

The processor core implements an additional hardware implementation-dependent register as shown in Figure E-29, not described in the *MPC603e User's Manual*. HID2 can be accessed with **mfspr** using SPR1011.

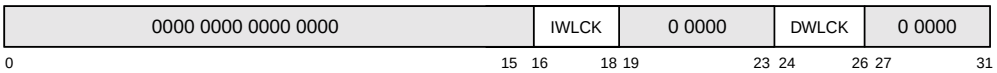

Figure E-29. Hardware Implementation-Dependent Register 2 (HID2)

Table E-23 describes the HID2 fields.

Table E-23. HID2 Field Descriptions

Bits	Name	Function
0–15	—	Reserved
16–18	IWLCK	Instruction cache way lock—Useful for locking blocks of instructions into the instruction cache for time-critical applications where deterministic behavior is required. Refer to Section 5.4.2.3, "Cache Locking," for more information.
19–23	—	Reserved
24–26	DWLCK	Data cache way lock—Useful for locking blocks of data into the data cache for time-critical applications where deterministic behavior is required. Refer to Section 5.4.2.3, "Cache Locking," for more information.
27–31	—	Reserved

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Glossary of Terms and Abbreviations

The glossary contains an alphabetical list of terms, phrases, and abbreviations used in this book. Some of the terms and definitions included in the glossary are reprinted from IEEE Std 754-1985, IEEE Standard for Binary Floating-Point Arithmetic, copyright ©1985 by the Institute of Electrical and Electronics Engineers, Inc. with the permission of the IEEE.

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A

Atomic. A bus access that attempts to be part of a read-write operation to the same address uninterrupted by any other access to that address (the term refers to the fact that the transactions are indivisible). The PowerPC 603e microprocessor initiates the read and write separately, but signals the memory system that it is attempting an atomic operation. If the operation fails, status is kept so that the 603e can try again. The 603e implements atomic accesses through the **lwarx**/**stwcx.** instruction pair.

B

Beat. A single state on the 603e bus interface that may extend across multiple bus cycles. A 603e transaction can be composed of multiple address or data *beats*.

Big-endian. A byte-ordering method in memory where the address n of a word corresponds to the most significant byte. In an addressed memory word, the bytes are ordered (left to right) 0, 1, 2, 3, with 0 being the most significant byte.

Burst. A multiple beat data transfer whose total size is typically equal to a cache block (in the 603e, a 32-byte block).

Bus clock. Clock that causes the bus state transitions.

Bus master. The owner of the address or data bus; the device that initiates or requests the transaction.

C

Cache. High-speed memory containing recently accessed data and/or instructions (subset of main memory).

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Cache block. The cacheable unit for a PowerPC processor. The size of a cache block may vary among processors. For the 603e, it is one cache line (8 words).

Cache coherency. Caches are coherent if a processor performing a read from its cache is supplied with data corresponding to the most recent value written to memory or to another processor's cache.

Cast-outs. Cache block that must be written to memory when a snoop miss causes the least recently used block with modified data to be replaced.

Context synchronization. Context synchronization is the result of specific instructions (such as **sc** or **rfi**) or when certain events occur (such as an exception). During context synchronization, all instructions in execution complete past the point where they can produce an exception; all instructions in execution complete in the context in which they began execution; all subsequent instructions are fetched and executed in the new context.

Copy-back operation. A cache operation in which a cache line is copied back to memory to enforce cache coherency. Copy-back operations consist of snoop push-out operations and cache cast-out operations.

D

Denormalized number. A nonzero floating-point number whose exponent has a reserved value, usually the format's minimum, and whose explicit or implicit leading significand bit is zero.

Direct-store segment access. An access to an I/O address space. The 603 defines separate memory-mapped and I/O address spaces, or segments, distinguished by the corresponding segment register T bit in the address translation logic of the 603. If the T bit is cleared, the memory reference is a normal memory-mapped access and can use the virtual memory management hardware of the 603. If the T bit is set, the memory reference is a direct-store access.

E

E**xception**. An unusual or error condition encountered by the processor that results in special processing.

Exception handler. A software routine that executes when an exception occurs. Normally, the exception handler corrects the condition that caused the exception, or performs some other meaningful task (such as aborting the program that caused the exception). The addresses of the exception handlers are defined by a two-word exception vector that is branched to automatically when an exception occurs.

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Exclusive state. EMI state (E) in which only one caching device contains data that is also in system memory.

Execution synchronization. All instructions in execution are architecturally complete before beginning execution (appearing to begin execution) of the next instruction. Similar to context synchronization but doesn't force the contents of the instruction buffers to be deleted and refetched.

F

Flush. An operation that causes a modified cache block to be invalidated and the data to be written to memory.

I

Instruction queue. A holding place for instructions fetched from the current instruction stream.

Integer unit. The functional unit in the 603e responsible for executing all integer instructions.

Interrupt. An external signal that causes the 603e to suspend current execution and take a predefined exception.

Invalid state. EMI state (I) that indicates that the cache block does not contain valid data.

K

Kill. An operation that causes a cache block to be invalidated.

L

Latency. The number of clock cycles necessary to execute an instruction and make ready the results of that instruction.

Little-endian. A byte-ordering method in memory where the address n of a word corresponds to the least significant byte. In an addressed memory word, the bytes are ordered (left to right) 3, 2, 1, 0, with 3 being the most significant byte.

Low-drop-out.A term used to describe linear power supplies that supply a stable output even when the V_{in}-V_{out} difference is low.

M

Memory-mapped accesses. Accesses whose addresses use the segmented or block address translation mechanisms provided by the MMU and that occur externally with the bus protocol defined for memory.

Memory coherency. Refers to memory agreement between caches and system memory (for example, EMI cache coherency).

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Memory consistency. Refers to levels of memory with respect to a single processor and system memory (for example, on-chip cache, secondary cache, and system memory).

Memory-forced I/O controller interface access. These accesses are made to memory space. They do not use the extensions to the memory protocol described for I/O controller interface accesses, and they bypass the page- and block-translation and protection mechanisms.

Memory management unit. The functional unit in the 603e that translates the logical address bits to physical address bits.

Modified state. EMI state (M) in which one, and only one, caching device has the valid data for that address. The data at this address in external memory is not valid.

O

Out-of-order. An operation is said to be out-of-order when it is not guaranteed to be required by the sequential execution model, such as the execution of an instruction that follows another instruction that may alter the instruction flow. For example, execution of instructions in an unresolved branch is said to be out-of-order, as is the execution of an instruction behind another instruction that may yet cause an exception. The results of operations that are performed out-of-order are not committed to architected resources until it can be ensured that these results adhere to the in-order, or sequential execution model.

P

Page. A 4-Kbyte area of memory, aligned on a 4-Kbyte boundary.

Park. The act of allowing a bus master to maintain mastership of the bus without having to arbitrate.

Pipelining. A technique that breaks instruction execution into distinct steps so that multiple steps can be performed at the same time.

Q

Quiesce. To come to rest. The processor is said to quiesce when an exception is taken or a **sync** instruction is executed. The instruction stream is stopped at the decode stage and executing instructions are allowed to complete to create a controlled context for instructions that may be affected by out-of-order, parallel execution. See **Context synchronization**.

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S

Scan interface. The 603e's test interface.

Slave. The device addressed by a master device. The slave is identified in the address tenure and is responsible for supplying or latching the requested data for the master during the data tenure.

Snooping. Monitoring addresses driven by a bus master to detect the need for coherency actions.

Snoop push. Write-backs due to a snoop hit. The block will transition to an invalid or exclusive state.

Split-transaction. A transaction with independent request and response tenures.

Split-transaction Bus. A bus that allows address and data transactions from different processors to occur independently.

Superscalar machine. A machine that can issue multiple instructions concurrently from a conventional linear instruction stream.

Supervisor mode. The privileged operation state of the 603e. In supervisor mode, software can access all control registers and can access the supervisor memory space, among other privileged operations.

T

Tenure. The period of bus mastership. For the 603e, there can be separate address bus tenures and data bus tenures. A tenure consists of three phases: arbitration, transfer, termination

Transaction. A complete exchange between two bus devices. A transaction is minimally comprised of an address tenure; one or more data tenures may be involved in the exchange. There are two kinds of transactions: address/data and address-only.

Transfer termination. Signal that refers to both signals that acknowledge the transfer of individual beats (of both single-beat transfer and individual beats of a burst transfer) and to signals that mark the end of the tenure.

U

User mode. The unprivileged operating state of the 603e. In user mode, software can only access certain control registers and can only access user memory space. No privileged operations can be performed.

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W

Write-through. A memory update policy in which all processor write cycles are written to both the cache and memory.

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